Fishery Data Series No. 18-04

Anchor River Chinook Salmon Escapement, 2010

by

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and

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December 2018

Alaska Department of Fish and Game Divisions of Sport Fish and Commercial Fisheries

Symbols and Abbreviations

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Weights and measures (metric)

centimeter	cm
deciliter	dL
gram	g
hectare	ha
kilogram	kg
kilometer	km
liter	L
meter	m
milliliter	mL
millimeter	mm

Weights and measures (English)

cubic feet per second	ft^3/s
foot	ft
gallon	gal
inch	in
mile	mi
nautical mile	nmi
ounce	oz
pound	lb
quart	qt
yard	yd

Time and temperature

day	d
degrees Celsius	°C
degrees Fahrenheit	°F
degrees kelvin	K
hour	h
minute	min
second	s

Physics and chemistry

all atomic symbols	
alternating current	AC
ampere	A
calorie	cal
direct current	DC
hertz	Hz
horsepower	hp
hydrogen ion activity (negative log of)	pH
parts per million	ppm
parts per thousand	ppt, ‰
volts	V
watts	W

General

Alaska Administrative Code	AAC
all commonly accepted abbreviations	e.g., Mr., Mrs., AM, PM, etc.
all commonly accepted professional titles	e.g., Dr., Ph.D., R.N., etc.
at	@
compass directions:	
east	E
north	N
south	S
west	W
copyright	©
corporate suffixes:	
Company	Co.
Corporation	Corp.
Incorporated	Inc.
Limited	Ltd.
District of Columbia	D.C.
et alii (and others)	et al.
et cetera (and so forth)	etc.
exempli gratia (for example)	e.g.
Federal Information Code	FIC
id est (that is)	i.e.
latitude or longitude	lat or long
monetary symbols (U.S.)	$, ¢
months (tables and figures): first three letters	Jan,...,Dec
registered trademark	®
trademark	™
United States (adjective)	U.S.
United States of America (noun)	USA
U.S.C.	United States Code
U.S. state	use two-letter abbreviations (e.g., AK, WA)

Mathematics, statistics

all standard mathematical signs, symbols and abbreviations	
alternate hypothesis	H_A
base of natural logarithm	*e*
catch per unit effort	CPUE
coefficient of variation	CV
common test statistics	(F, t, χ^2, etc.)
confidence interval	CI
correlation coefficient (multiple)	R
correlation coefficient (simple)	r
covariance	cov
degree (angular)	°
degrees of freedom	df
expected value	*E*
greater than	$>$
greater than or equal to	$\geq$
harvest per unit effort	HPUE
less than	$<$
less than or equal to	$\leq$
logarithm (natural)	ln
logarithm (base 10)	log
logarithm (specify base)	$\log_2$, etc.
minute (angular)	'
not significant	NS
null hypothesis	H_O
percent	%
probability	P
probability of a type I error (rejection of the null hypothesis when true)	α
probability of a type II error (acceptance of the null hypothesis when false)	β
second (angular)	"
standard deviation	SD
standard error	SE
variance	
population	Var
sample	var

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ABSTRACT

The 2010 Anchor River Chinook salmon (*Oncorhynchus tshawytscha*) escapement was estimated using dual-frequency identification sonar (DIDSON) during high-spring flows and then censused using a resistance board weir when flows subsided. The Chinook salmon escapement, an estimated 4,449 fish (SE 103), fell below the lower bound of the sustainable escapement goal (SEG) of 5,000 fish and was the second lowest on record. The midpoint of the Chinook salmon run was 10 June. The Chinook salmon daily escapement counts were positively correlated (r = 0.56, df = 45, P < 0.0001) with average daily river stage. The dominant age class was ocean age 3 (51.3%, SE 3.2%). Overall mean length of males (635 mm, SE 11 mm) was smaller than that of females (762 mm, SE 7 mm).

Key words: Anchor River, Chinook salmon, *Oncorhynchus tshawytscha*, *Oncorhynchus mykiss,* kelt emigration, run timing, diel, diurnal, lower bound SEG, stock status, weir, sonar, DIDSON.

INTRODUCTION

The Anchor River is located on the southern portion of the Kenai Peninsula (Figure 1) and supports the largest Chinook salmon (*Oncorhynchus tshawytscha*) run in the Lower Cook Inlet Management Area (LCIMA) with estimated total runs ranging from about 4,200 to 13,600 fish (2003–2009; Kerkvliet et al. 2016). There are 3 streams open to sport fishing for Chinook salmon in the LCIMA: Anchor River, Deep Creek, and Ninilchik River. In Alaska, most juvenile Chinook salmon remain in fresh water until the following spring when they migrate to the ocean as smolt in their second year. Based on scale age data, Anchor River Chinook salmon spend 1 to 4 years feeding in salt water before they return to spawn (Kerkvliet and Booz 2012). Run timing of adult Chinook salmon into these streams is approximately early May through late July with a peak in early to mid-June (Kerkvliet et al. 2008; Kerkvliet and Burwen 2010; Kerkvliet and Booz 2012; Kerkvliet et al. 2012).

The Anchor River watershed is approximately 587 km^2 with about 266 river kilometers (RKM) of anadromous streams (Table 1). The Anchor River has 2 major forks (south and north forks) and their confluence is located approximately 2.8 RKM upstream from the mouth. The south fork watershed is approximately twice the size as the north fork watershed. Because of the Anchor River's small size, geomorphology, and vegetation, water flows can rise substantially following heavy rains.

Anchor River Chinook salmon are primarily harvested during an inriver sport fishery. The inriver sport fishery is restricted by regulation through small daily and seasonal bag limits, and limited numbers of days and areas are open to sport fishing. The annual Chinook salmon catch and harvest in the Anchor River sport fishery is estimated by the ADF&G Statewide Harvest Survey (SWHS; Table 2). From 2003 to 2009, the average SWHS Chinook salmon inriver harvest was 1,386 fish. An unknown number of Anchor River Chinook salmon are also harvested in a mixed-stock sport troll fishery within Cook Inlet near the river mouth, but this harvest is assumed to be small (Szarzi et al. 2007a).

Before 2003, enumerating the Anchor River Chinook salmon escapement over the entire run was problematic because traditional methods could not operate in the river's periodic high and low water conditions. Traditional weir methods (fixed picket or resistance board weirs) commonly used in small streams could not be installed in the Anchor River in May and early June because the river is typically too high and swift in that season for installation. Likewise, traditional sonar methods (e.g., split-beam sonar) commonly used in large Alaskan rivers at the time (e.g., the Kenai River) were not suited for smaller streams like the Anchor River because of periodic low water conditions that are too shallow to insonify. Therefore, an annual aerial survey was conducted during peak spawning to index and evaluate Chinook salmon escapement (Appendix A1). However, because of the inherent biases associated with the index counts (e.g., differences in survey conditions and surveyor biases), year-to-year comparisons of Chinook salmon escapement remained difficult.

In 2003, a new dual-frequency identification sonar (DIDSON) manufactured by Sound Metrics Corporation (SMC)[1] was used to monitor Chinook salmon escapement in the Anchor River with near video-quality images (Kerkvliet et al. 2008). The DIDSON was deployed on the mainstem of the Anchor River just below the confluence of the north and south forks and just upstream of the fishery at a site where the river profile was relatively level (Figure 2).

The 2003 Anchor River Chinook salmon count (9,238 fish) was higher than expected even though the DIDSON began operating in late May after the beginning of the run and stopped operating in early July before the run had ended (Table 3). It is estimated that the count in 2003 represented about 70% of the true escapement based on the average proportion of the run that escaped during that time in 2004 and 2005 (2 years with similar water temperatures and flow rate patterns). From 2004 to 2008, the entire Chinook salmon escapement was estimated using the DIDSON during high discharge rates in the early spring through early to mid-June, and a resistance board weir was used thereafter for the rest of the season. In 2009, the DIDSON was not required because low water levels allowed for the immediate installation of the resistance board weir, which provided the first complete Anchor River Chinook salmon escapement census.

Anchor River Chinook salmon escapement counts based on DIDSON have a negative bias and underestimate escapement because all sonar images of fish swimming upstream and downstream are assumed to be Chinook salmon even though an unknown portion of the downstream sonar images (which are subtracted from the escapement count) include postspawning steelhead (*Oncorhynchus mykiss*) kelts emigrating out of the river. In 2009 with the early weir installation, both emigrating kelts and immigrating Chinook salmon were monitored at the sonar-weir site (Kerkvliet and Booz 2012). The midpoint of the 2009 kelt emigration (7 June) was earlier than the midpoint of the Chinook salmon immigration (23 June). Given a typical weir installation date of early to mid-June, and assuming the timing of the kelt emigration in 2009 was typical, then a large portion of the kelt emigration may occur during the DIDSON operation. Based on the census of immigrating Chinook salmon and emigrating kelts in 2009, the negative bias when using the DIDSON would be at most 17%. Note that this percentage is based on the lowest escapement of Chinook salmon between 2003 and 2009. A similar outmigration of steelhead during the highest measured Chinook salmon run would translate to a negative bias of about 5%.

Since 2003, the annual Chinook salmon escapement in the Anchor River has ranged from 3,455 (SE 0) to 12,016 (SE 283; Table 4). Inriver exploitation rates (percentage of the total run that is harvested) have ranged from 9.9% in 2003 to 21.7% in 2008; however, estimated exploitation in 2003 is positively biased and the estimate may be high because the escapement was not completely enumerated due to project operation dates.

In the fall of 2007, under the guidelines established in the *Policy for the Management of Sustainable Salmon Fisheries* (Alaska Administrative Code 5 AAC 39.222) and *Policy for*

[1] Product names and manufacturers used in this publication are included for completeness but do not constitute product endorsement.

Statewide Salmon Escapement Goals (5 AAC 39.223), Division of Sport Fish (SF) established a lower bound[2] sustainable escapement goal (SEG) of 5,000 Chinook salmon (Appendix A2). The goal was derived from a full probability spawner–recruit model using all available data, including 31 years (1977–2007) of aerial survey escapement indices and the SWHS inriver harvest estimates, plus 5 years (2003–2007) of weir-sonar estimates of escapement and age composition (Szarzi et al. 2007a). Additionally, the Alaska Board of Fisheries (BOF) liberalized the fresh and saltwater fisheries to provide additional harvest opportunities on Anchor River Chinook salmon through several regulation changes (Appendix A3). Since 2008, the fishery has been managed under these new changes.

This report is part of a continuing series that evaluates the Anchor River Chinook salmon stock. The Chinook salmon escapement estimates will be used in future escapement goal analyses and also to manage the fishery according to the *Management of Sustainable Salmon Fisheries* and *Statewide Salmon Escapement Goals* policies.

OBJECTIVES

Primary Objectives

1) Estimate the Anchor River Chinook salmon escapement that passes upstream of 2.8 RKM (approximately 2 river miles) from the river mouth.
2) Estimate the age and sex composition of the Chinook salmon escapement.

Secondary Objectives

1) Estimate length-at-age and sex of the Chinook salmon escapement.
2) Examine between-reader and within-reader variation of DIDSON counts.
3) Determine seasonal run timing of Chinook salmon, diel[3] run timing of Chinook salmon during DIDSON operation and U.S. Fish and Wildlife Service (USFWS) weir operation, and diurnal[4] run timing of Chinook salmon during SF weir operation.
4) Measure water depth and temperature throughout the project operation.
5) Examine all Chinook salmon sampled for age, sex and length (ASL) for an adipose fin.

METHODS

OPERATION DATES AND EQUIPMENT

Anchor River Chinook salmon escapement was monitored at RKM 2.8 approximately 0.02 RKM downstream of the north and south forks confluence (Figure 3). In 2010, the escapement was estimated from 13 May at 1700 hours through 8 June at 1200 hours using the DIDSON (Figure 4). The resistance board weir (Figure 5) became operational on 8 June at 1300 hours and was operated continuously through 29 September at 0800 hours. During weir operation, all fish were identified to species and a census of Chinook salmon escapement was obtained. From 8 June through 1 August, the weir was operated by SF; thereafter, the weir was operated through

[2] Terminology revised from “threshold” to “lower bound” to prevent confusion with a sustained escapement threshold (SET) defined in the *Sustainable Salmon Fisheries* policy.

[3] “Diel” is defined as “of or pertaining to a 24 h period.”

[4] “Diurnal” is defined as “occurring daily during the daytime rather than at night.”

29 September by USFWS through a cooperative agreement to monitor coho salmon escapement and to continue to monitor Chinook salmon escapement. On 2 August, USFWS incorporated an underwater video system in the weir and assumed responsibility for monitoring escapement and weir operation. The methods associated with the underwater video system are described in Anderson and Stillwater Sciences (2011).

During DIDSON operation, beach seines were used to capture Chinook salmon for ASL estimation and to estimate the species composition upstream of the DIDSON site on the north and south forks. The south fork was netted 3 times (3, 9, and 10 June), and the north fork was netted twice (25 May and 1 June). During the SF weir operation, live boxes (Figure 5) were used to capture Chinook salmon for ASL samples. No ASL samples were collected during USFWS weir operation.

DIDSON and Partial Picket Weirs

In 2010, the standard sonar lens (used from 2003 to 2008) was replaced with an ultra-high resolution large lens ("large lens"). The large lens almost doubles the resolution of the standard lens and has a smaller vertical beam pattern. The resolution of the large lens is better at the longer ranges needed at the Anchor River and is preferred over the standard lens. The highest image resolution is still achieved when the DIDSON is operated at shorter ranges using the higher of 2 available frequencies. Further details on factors influencing DIDSON resolution can be found in Appendix B1 and Burwen et al. (2007, 2010).

Because the width of the Anchor River under high water conditions at the monitoring site (approximately 31 m) is greater than the effective range of the DIDSON (approximately 20 m), a partial weir was installed on each bank to narrow the insonified corridor to 20 m or less (Figures 3 and 4). The weirs were tripod and picket structures that could be removed or extended as necessary due to changing water levels. During the initial installation, the weirs were extended to narrow the insonified corridor to about 17 m. As water flows resided, the weirs were extended farther to narrow the insonified corridor. All bottom irregularities at the base of the partial weir were sealed using sandbags that prevented fish from migrating past the DIDSON undetected.

The DIDSON was first enclosed in a SMC silt protection box and then mounted on a Remote Ocean Systems PT-25 pan-and-tilt unit to allow precise aiming. The sonar and remote aiming unit were deployed on a tripod-style mount as described in Burwen et al. (2010). The communication cables from the DIDSON lead to electronics inside a WeatherPort tent. DIDSON data were stored and processed on a Dell desktop computer. Data were collected using DIDSON software (version V5.21.09, provided by the manufacturer, Sound Metrics Corporation). DIDSON data files were saved every 20 minutes for each hour and designated as first, second, and third 20-minute counts. All electronics were powered by a 2000 W generator.

The DIDSON was positioned approximately 0.5 m upstream and no less than 3 m from the terminal end of the left bank weir (the left bank is defined as the left side of the river when facing downstream; Figure 3). The DIDSON lens was aimed slightly downward across the insonified corridor and was positioned at least 10 cm off the river bottom. The aim of the DIDSON resulted in an insonified cone to the terminal edge of the right bank weir that ensured full coverage of the migration corridor. As water conditions changed, the exact position and aim were changed to produce the best resolution images. During lower water levels, an artificial target (10 lb lead downrigger ball) was dragged along the bottom between the weirs to ensure that the sonar beam was adequately covering the migration corridor.

The DIDSON was primarily operated at low frequency with a window length of 20 m. However, during especially turbid conditions, the second and third 20-minute files in each hour were set to opposite 10 m ranges (0–10 m and 10–20 m), and a summed count of those files was used in place of the first 20-minute file. Detailed descriptions of these settings are found in Appendix B2.

Resistance Board Weir

The water level dropped sufficiently to install the resistance board weir on 8 June. The resistance board weir (length approximately 31 m long) was installed approximately 6 m downstream from the DIDSON and partial weirs. Picket spacing for the resistance board weir and live boxes was approximately 2.8 cm (1.5 in) to block the passage of all but the smallest ocean-age-1 Chinook salmon (Figure 5). All bottom irregularities along the base of the resistance board weir were sealed using sand bags and a fencing skirt. Two live boxes were incorporated into the weir to trap upstream migrating fish. One live box was placed in relatively shallow water near the left bank and a second in midchannel. The left bank live box enabled the crew to pass fish through the weir during high water events that prevented safe access to the midchannel live box or when visibility was limited due to high turbidity or deeper water.

The weir was visually inspected on a daily basis for holes to ensure no fish could migrate past undetected. During the SF weir operation, the gate to the live box was opened daily from approximately 0800 hours to approximately midnight or earlier depending on darkness. To avoid impeding fish passage, technicians periodically checked the live box and processed all fish as quickly as possible. On 2 August, the midchannel live box was replaced with the underwater video system (Anderson and Stillwater Sciences 2011). The left bank live box was also removed.

In June, a steelhead chute was formed near the thalweg by weighting the downstream end of a resistance board weir panel with a sandbag. The weight of the sand bag allowed a shallow stream of water that steelhead could use to swim downstream over the weir. The placement of the sand bag was used to adjust the water depth flowing over the weir panel so that it was deep enough to allow steelhead (kelts) to swim downstream, but shallow enough to prevent upstream migration.

ESCAPEMENT MONITORING

DIDSON

In 2010, images of fish moving either upstream or downstream were counted for at least one 20-minute file for each hour the DIDSON was operated with the exception of 5 hours when the computer malfunctioned and counts were linearly interpolated for this period. The counts from the 20-minute files were then expanded to the hour. Both upstream and downstream moving images were counted and all were assumed to be Chinook salmon. DIDSON counts were treated as follows:

1) DIDSON images of fish moving upstream were assumed to be Chinook salmon. However, this assumption is flawed to some degree, as follows. In 2003 when DIDSON was operated for the full season, pink salmon (*Onchorhynchus gorbuscha*) and Dolly Varden (*Salvelinus malma*) were captured in beach seines from 18 June through 10 July and the DIDSON counts were adjusted accordingly (Kerkvliet et al. 2008). Since 2004, the latest the DIDSON was operated was 16 June and most of the beach seine catches have been Chinook salmon with some steelhead (mainly postspawning steelhead). The early installation of the weir from 2004 to 2010 (range from 12 May to 16 June) has

meant that any pink salmon immigration was censused at the weir (along with Chinook salmon), alleviating the need for adjustments to upstream DIDSON counts. In 2009 when the weir was operated at the beginning of the Chinook salmon run due to low river conditions, 13 of the 14 steelhead counted moving upstream of the weir from 12 May through 30 June were postspawning steelhead, indicating that for years when the DIDSON was operated during this time period, it is likely that a low number of the upstream counts are steelhead and not Chinook salmon (Kerkvliet et al. 2012). Historically, upstream DIDSON counts have not been adjusted for the low numbers of steelhead considered to be moving upstream during this time.

2) Images of fish moving downstream were assumed to be Chinook salmon. This assumption is also flawed to some degree; it is known that a portion of the downstream counts include postspawning steelhead emigrating from the river. No adjustments were made to the downstream counts because it is impossible to differentiate downstream moving Chinook salmon from steelhead, and this assumption provides a conservative count because any downstream steelhead movement past the DIDSON leads to an underestimation of the Chinook salmon escapement.

Resistance Board Weir

All fish were identified by species and counted by the hour in which they passed through the live box. Hourly counts were summarized to produce daily escapement counts.

During the USFWS operation of the weir, the underwater video system allowed fish to pass 24 hours per day. Fish passage data were collected on a digital video recorder (DVR). Recordings were reviewed daily to produce timely daily escapement counts. All fish were identified to species and counted by their recorded hour (Anderson and Stillwater Sciences 2011). Hourly counts were summarized to produce daily escapement counts.

BIOLOGICAL AND ENVIRONMENTAL SAMPLING

Beach Seine ASL Samples

During DIDSON operation, Chinook salmon were captured upstream of the sonar site on the north and south forks of the Anchor River using a beach seine net (30.5 m long by 2 m deep with 5.1 cm stretched mesh size. The net was fished by drifting it through deep pools (Kerkvliet et al. 2008).

All captured fish were identified by species, and the mid eye to tail fork (METF) length was measured to the nearest 5 mm. Sex was visually determined through external characteristics (such as kype development or a protruding ovipositor) and 3 scales were collected from each Chinook salmon for aging (Welander 1940). The upper lobe of the caudal fin was also clipped on each captured fish before release to prevent double sampling.

Scales were aged using a microfiche reader and with methods described by Welander (1940). Scales were aged without reference to size, sex, or other data. Scale samples were aged twice to estimate within-reader variability. Since 2007, the same individual has aged Anchor River Chinook salmon scales; the individual is tested annually with known aged scales (from recovered coded-wire-tagged fish). All scale samples that had conflicting ages for the 2 estimates were re-aged to produce a resolved age that was used for composition and abundance estimates.

Resistance Board Weir ASL Samples

Throughout the SF weir operation, Chinook salmon ASL sampling was conducted every other day by applying a sampling proportion of 0.12 to the cumulative Chinook salmon weir count since the last sampling event and rounding up to the nearest whole number. The sampling rate was based on historical run data. Chinook salmon sampling started when the weir was opened at approximately 0800 hours and was continuous until the daily sampling goal was met. Sampling was discontinued during the USFWS weir operation.

The upper lobe of the caudal fin was clipped on all Chinook salmon sampled for ASL to prevent double sampling in case of a weir failure. ASL data were collected and scales were aged as detailed above.

Adipose Fin Inspection

Each Chinook salmon captured with a beach seine or sampled at the SF weir was inspected for the presence of an adipose fin. Fish missing an adipose fin, indicating a hatchery-reared fish, were sacrificed and the heads were sent to the ADF&G Mark, Tag, and Age Lab to identify the release site using coded wire tag (CWT) information recovered from the head. Recovered CWTs were used to validate age data. Throughout the USFWS weir operation, only the presence or absence of an adipose fin was noted for the Chinook salmon that passed through the weir.

Environmental Data

Water temperatures were collected in degrees Fahrenheit daily at about 1000 and 1900 hours at the sonar-weir site using a hand-held thermometer; recorded data were subsequently converted to degrees Celsius. Approximately 0.1 RKM downstream of the sonar-weir site, Cook Inletkeeper (CIK), a citizen-based nonprofit group, collected water temperatures in degrees Celsius every 15 minutes using a temperature logger installed on 9 June. Daily temperature recordings provided in this report are based on hand-held temperature readings from 8 May through 8 June; thereafter, daily temperatures (average, minimum, and maximum) were averaged from logger readings collected every 15 minutes from midnight to midnight.

The U.S. Geological Survey (USGS) collected river stage data every hour from the gauge station (USGS 15239900) located on the south fork at approximately 11.4 RKM from the mouth of the Anchor River at a bridge on the New Sterling Highway.

DATA ANALYSIS

Escapement

Net DIDSON counts from 20-minute files within the jth hour (j = 1, . . . 24) of the kth day of the season were calculated as follows:

$$n_{jk} = u_{jk} - d_{jk} \tag{1}$$

where

u_{jk} = upstream counts in hour j of day k, and

d_{jk} = downstream counts in hour j of day k.

Net upstream counts for each hour were estimated as follows:

$$\hat{c}_{jk} = \frac{60}{t_{jk}} n_{jk} \tag{2}$$

where t_{jk} is the number of minutes sampled during the jth hour on day k (target is 20 minutes).

The following formula was used to linearly interpolate the count for hour j of day k in the rare situation where no data were available for a full hour due to computer malfunction, silting of sonar lens, etc.:

$$\hat{I}_j = C_{last} + \left[\frac{C_{next} - C_{last}}{d}\right] x_j \tag{3}$$

where

C_{last} = average of the expanded counts for the last 2 hours when counts are available,

C_{next} = average of expanded counts for next 2 hours when counts are available,

d = number of hours of missing data, and

x_j = number of hours between hour j and hour of last available count.

The number of hours for which there is no count is very small and these adjustments are not thought to contribute any meaningful bias or variance to the season-end estimates.

Hourly count estimates ($\hat{c}_{jk}$) were summed to provide daily estimates of escapement (C_k) and an estimate of the total escapement passage (C_D) during DIDSON system operation:

$$\hat{C}_k = \sum_{j=1}^{24} \hat{c}_{jk} \tag{4}$$

and

$$\hat{C}_D = \sum_{k=1}^{K} \hat{C}_k \ , \tag{5}$$

where K is the total number of days of operation of the DIDSON system in the year in question.

The variance of $\hat{C}_D$ was estimated as follows:

$$\mathrm{var}(\hat{C}_D) = \sum_{k=1}^{K} \mathrm{var}(\hat{C}_k) = \sum_{k=1}^{K}\sum_{j=1}^{24} \mathrm{var}(\hat{c}_{jk}) \ , \tag{6}$$

where

$$\mathrm{var}(\hat{c}_{jk}) = \left[\frac{60}{t_{jk}}\right]^2 \mathrm{var}(n_{jk}) = \left[\frac{60}{t_{jk}}\right]^2 s^2 \left[1 - \frac{t_{jk}}{60}\right], \tag{7}$$

and where s^2 is calculated as the successive difference estimate of variance for a systematic sample (Wolter 1985):

$$s^2 = \frac{\sum_{h=2}^{H}(n_h - n_{h-1})^2}{2(H-1)}, \tag{8}$$

where n_h is the hth sample count (h = 1 corresponds to the first count of the season [j = 1, k = 1] and h = H corresponds to the last count of the season [j = 24 and k = K]).

The estimated total Chinook salmon passage over the entire season was calculated as follows:

$$\hat{C}_T = \hat{C}_D + C_W, \tag{9}$$

where C_W is the count of Chinook salmon through the weir during both SF and USFWS operation; the variance of $\hat{C}_T$ was estimated as follows:

$$\mathrm{var}(\hat{C}_T) = \mathrm{var}(\hat{C}_D). \tag{10}$$

On the first day of DIDSON operation, the daily expanded net count was a negative fish count. The count was culled and the daily count set to 0 fish to reduce negative bias. This adjustment was considered justified given our assumption that the downstream swimming fish images are Chinook salmon; the upstream passage of these fish would not have been recorded yet (DIDSON not installed yet) and therefore should not be included as the first day's count.

Count Diagnostics

Re-counted DIDSON files provided a measure of reproducibility for escapement counts and a quality control measure. Between-reader variability was assessed for the 2 crewmembers (primary readers) responsible for counting DIDSON files by comparison with a third crewmember (secondary reader). Within-reader variability was assessed for the 2 primary readers.

Between-reader variability was assessed by comparing counts from the primary and secondary readers for three 20-minute files each day. Within-reader variability for the primary readers was assessed by comparing counts from three 20-minute DIDSON files each day (i.e., each file was read twice by a reader). Re-counted files were chosen to represent challenging counting conditions (e.g., high upstream and downstream counts and milling activity); the analysis therefore revealed worst-case scenarios of between- and within- reader variability. The following statistics were calculated for the between- and within-reader analyses:

1) Kendall's tau was calculated for each pair of counts for the same files as well as for all first and second readings. (Kendall's tau ranges from −1 to 1, representing perfect negative and positive correlation, respectively).

2) Intraclass correlation coefficient r was calculated for each pair of readers counting the same files (Shrout and Fleiss 1979). This statistic is a function of both the correlation and agreement between counts. It ranges from 0 to 1; it is high when there is little variation between the scores given to each count. The function icc() in the R package $\{\mathrm{irr}\}$ was used with model argument set to "twoway" and type argument to "agreement."

3) A Tukey difference plot was made for each pair of counts for the same files (Bland and Altman 1986). These plots are of differences between counts against the average of the scores of the readers.

Run Timing

Chinook salmon run timing at the sonar-weir site was described using cumulative daily counts and associated percentiles. The midpoint of the Chinook salmon run was defined as the date nearest the 50% cumulative count. The correlation of daily counts with daily river stage averages and river temperatures was examined with Pearson's correlation coefficient (r) for the middle 80% of the run. The hypothesis that there was no correlation ($r = 0$) was tested.

Diel run timing was evaluated using 24-hour DIDSON counts and video weir counts. During the SF weir operation, diurnal timing was calculated from the number of Chinook salmon that were passed through the weir live boxes during normal hours of operation (0800 through midnight). The hourly DIDSON and video weir counts were expressed as the percentage of fish counted each hour of a given day.

Age and Sex Composition and Length-at-Age

Age and sex composition during DIDSON operation was estimated from pooled samples obtained from beach seining in the north and south forks upstream of the sonar. Although statistically significant, age composition differences between the forks in 2003 and 2004 were not biologically significant; in 2005 and 2006, few fish were found in the north fork. Pooled beach seine samples derived from equal effort from the north and south forks are thought to be the best way to obtain a representative sample of the migration occurring during sonar operation (Kerkvliet et al. 2008).

Age and sex composition during the mainstem weir operation was estimated from systematic sampling at the weir.

The estimated proportion of Chinook salmon of age or sex class k (or a combination thereof) in the escapement during a given period x (where x is either W [Weir] or D [DIDSON]) was calculated as follows:

$$\hat{p}_{xk} = \frac{n_{xk}}{n_x}, \tag{11}$$

where

n_{xk} = the total number of salmon of age or sex class k in n_x and

n_x = the number of salmon sampled during period x.

The estimated proportion of Chinook salmon of age or sex class k (or a combination thereof) in the entire escapement to the Anchor River was calculated as follows:

$$\hat{p}_k = \phi_D \hat{p}_{Dk} + (1 - \phi_D)\hat{p}_{Wk}, \tag{12}$$

where ϕ_D is the proportion of the entire escapement that migrated during DIDSON operation (treated as a constant), and the estimated variance of proportion $\hat{p}_k$ was calculated as follows:

$$\mathrm{var}(\hat{p}_k) = \phi_D^2 \left[\left(\frac{\hat{C}_D - n_D}{\hat{C}_D} \right) \frac{\hat{p}_{Dk}(1-\hat{p}_{Dk})}{n_D - 1} \right] + (1-\phi_D)^2 \left(\frac{C_W - n_W}{C_W} \right) \frac{\hat{p}_{Wk}(1-\hat{p}_{Wk})}{n_W - 1}. \tag{13}$$

$\hat{C}_D$ from Equation 5 is measured with high precision and is included in the finite population correction factor in Equation 13 as a constant.

The estimated total number of Chinook salmon of age or sex class *k* was calculated as follows:

$$\hat{N}_k = \hat{C}_T \ \hat{p}_k, \tag{14}$$

where C_T is calculated in Equation 9.

The estimated variance of $\hat{N}_k$ was calculated as follows (Goodman 1960):

$$\mathrm{var}(\hat{N}_k) = \hat{C}_T^{\,2}\ \mathrm{var}(\hat{p}_k) + \hat{p}_k^2\ \mathrm{var}(\hat{C}_T) - \mathrm{var}(\hat{p}_k)\,\mathrm{var}(\hat{C}_T). \tag{15}$$

Mean lengths-at-age and their variances were estimated using standard summary statistics.

The within-reader variability of Chinook salmon scale age estimates was calculated using a coefficient of variation (CV) expressed as the ratio of the standard deviation over the mean age (Campana 2001):

$$CV_j = 100\% \times \frac{\sqrt{\sum_{i=1}^{R} \frac{(X_{ij} - X_j)^2}{R-1}}}{X_j} \tag{16}$$

where

X_{ij} = the *i*th age estimate of the *j*th fish,

X_j = the mean age estimate of the *j*th fish, and

R = the number of times each fish is aged.

RESULTS

ESCAPEMENT

The estimated 2010 Anchor River Chinook salmon escapement of 4,449 fish was below the SEG lower bound of 5,000 fish (Table 4, Appendix C1). The escapement was based on sonar counts (2,064 fish, SE 103) (Appendix D1) and counts from the SF traditional weir (2,243 fish) and USFWS (108 fish) video weir operation.

The sonar portion of the escapement was based on counts from 14 May through 8 June (1,111 upstream and 427 downstream swimming fish; Figure 6). During this period, the ratio of upstream to downstream moving fish averaged 2.6:1.0. The 13 May sonar count was set to 0 fish because the expanded sonar estimate (−12 fish) introduced a negative bias.

During netting, only Chinook salmon and steelhead were captured (Table 5). Steelhead accounted for 13% (16/124) of all fish caught. No adjustments were made to the upstream DIDSON counts based on netting composition. During the June weir operation, 2 steelhead were observed on the upstream side of the weir (one on 9 June and one on 15 June), but no steelhead were observed passing downstream through the steelhead chute.

COUNT DIAGNOSTICS

Between-reader variability was evaluated for 73 DIDSON files (Table 6). Correlations (Kendall's tau) between the primary readers (1 and 2) and the secondary reader (3) were 0.92 (readers 1 vs. 3) and 0.84 (readers 2 vs. 3). Intraclass correlations were high (r = 0.94 for readers 1 vs. 3 and r = 0.98 for readers 2 vs. 3). Percent agreements were 82% (readers 1 vs. 3) and 73% (readers 2 vs. 3). Tukey difference plots indicate between-reader counts were more variable for low counts for reader pairing 2 vs. 3 but not for pairing 1 vs. 3 (Figure 7). Differences in counts between specific reader pairs are also shown in Table 6.

Within-reader variability was also evaluated for 73 (different) DIDSON files; results are shown in Table 6. Only primary readers 1 and 2 were assessed. Correlations (Kendall's tau) for primary readers were 0.81 (reader 1) and 0.77 (reader 2). Intraclass correlations were 0.85 (reader 1) and 0.97 (reader 2). Percent agreements were 67% (reader 1) and 76% (reader 2). Tukey difference plots indicate within-reader counts were more variable for low counts for reader 2 (Figure 8). Differences in counts within specific readers are also shown in Table 6.

RUN TIMING

The midpoint of the Anchor River Chinook salmon run was 10 June (Figure 9, Appendix C1). The middle 80% of the run was counted from 29 May to 14 July (48 days).

During DIDSON operation (24 hours daily), most of the upstream and downstream counts (approximately 87% and 80%, respectively) were counted from 1400 hours to 0559 hours (Figure 10). Peak upstream counts occurred at 0100, 0300, and 0400 hours. Peak downstream counts occurred at 0400, 1900, and 2200 hours.

During the SF weir operation (0800 to midnight), most (about 94%) of the Chinook salmon were counted from 1400 to 2059 hours and peak counts occurred at 1800 and 2000 hours (Figure 11). During the USFWS video weir operation (24 hours daily), most of the Chinook salmon (82%) were counted through the weir from 1400 to 0559 hours and peak counts occurred at 1800 and 1900 hours (Figure 12).

River levels remained low from late June through 13 July (Figure 13 and Appendix E1). During this low water period, fish passage through the weir was low although large numbers of maturing Chinook salmon were observed holding throughout the river downstream of the weir in deep pools and channels. Late in the evening on 12 July, the river began rising from recent rains. By 14 July, the river had risen 22.9 cm. During this 3 day period, the final large pulse of Chinook salmon (n = 333) passed through the weir (Appendices C1 and E1).

During the middle 80% of the Chinook salmon run, daily counts were positively correlated with average river stage (r = 0.56, df = 45, P < 0.0001; Figure 13) but not average river temperature (r = −0.25, df = 42, P = 0.10; Figure 14). Average water temperature was negatively correlated with average river stage (r = −0.70, df = 42, P < 0.001). During the middle 80% of the run, river stage averaged 35.2 cm (range 21.9–66.4 cm) and river temperature averaged 10.2°C (range 6.0–13.7°C) (Appendices E1 and E2).

AGE AND SEX COMPOSITION AND LENGTH-AT-AGE

There were 106 Chinook salmon sampled from netting for ASL analysis of which 82 had readable scales. Of the 234 Chinook salmon sampled from the weir live box, 191 had readable scales. Netting effort was extended beyond DIDSON removal (8 June) for an additional 2 days because the number of ASL samples collected was insufficient to characterize the age composition during the sonar period. The coefficient of variation of all age estimates from Chinook salmon scales was 1.54%.

Ocean-age-3 was the dominant age class (51.3%, SE 3.2%) for the 2010 Anchor River Chinook salmon escapement (Table 7). Ocean-age-2 was the dominant age class for males (31.1%, SE 2.9%), whereas ocean-age-3 was the dominant age class for females (27.9%, SE 2.9%). The overall mean length of males (635 mm, SE 11 mm) was smaller than females (762 mm, SE 7 mm). The sex ratio was 1.7 males to 1 female.

ADIPOSE FIN INSPECTION

The adipose fin was present on all 487 Chinook salmon examined, indicating none of these were hatchery-reared fish and therefore none had CWTs. Most Chinook salmon were examined during ASL sampling from the live box (n = 237) and from beach seine catches (n = 108) and the remaining 142 Chinook salmon were examined from video files.

DISCUSSION

The 2010 Chinook salmon estimated escapement of 4,449 fish was below the sustainable escapement goal (SEG) lower bound of 5,000 fish and was the second lowest since 2003. The 2008–2010 average escapement (4,570 fish) was considerably lower than the preceding 2004–2007 average (10,435 fish; Table 4). Chinook salmon escapements for other LCI streams were also low in 2010. The Chinook salmon aerial survey index for Deep Creek was below its historical average, but fell within the SEG range by 37 fish, and the Ninilchik River escapement index fell within the SEG range by 62 wild Chinook salmon (Szarzi et al. 2010).

In 2010, Chinook salmon sport fishery openings were scheduled on the 3-day weekend before Memorial Day weekend followed by the 4 consecutive 3-day weekends and the 5 Wednesdays following each weekend (Appendix A3). As the Anchor River Chinook salmon run approached the historical midpoint in 2010, escapement was projected to fall near or below the SEG so a series of emergency orders (EO) were issued to reduce harvest. The first EO prohibited the use of bait in the Anchor River and extended the closed area surrounding the mouth north and south from 1 to 2 miles and was issued before the third weekend opening. This EO also prohibited use of bait in Deep Creek and the Ninilchik River to prevent overharvest of Chinook salmon from a possible influx of anglers displaced from closures on the Kenai River for Chinook salmon and on the Kasilof River for wild Chinook salmon. The second EO prohibited the harvest of Chinook salmon in the Anchor River and was issued before the fourth opening weekend. The third EO maintained the marine closed area surrounding the Anchor River mouth. The third EO was later rescinded effective 13 July when it appeared there weren’t significant numbers of Anchor River Chinook salmon available to be intercepted in the nearby marine fishery (Szarzi et al. 2010).

Compared to the last 7 years, the 2010 run (4,813 fish) was closest in number to the 2009 run (4,192 fish; Table 4). However, median run timing in 2010 (10 June) was more similar to the 2004–2008 average median (9 June) than to the 2009 median (23 June; Figure 9). Although

Chinook salmon harvest was allowed for 12 days (through the third Wednesday opening) in both 2009 and 2010 before harvest was prohibited, exploitation was estimated to be 10 percentage points lower in 2010 compared to 2009 (Table 4). It is likely that the low river levels in 2009 versus 2010 provided better fishing conditions and contributed to higher exploitation because more Chinook salmon were holding within the fishery area.

The large final pulse of Chinook salmon in July 2010 was not unprecedented; a similar late pulse was also observed in 2007 (Kerkvliet et al. 2012). In both years, Chinook salmon holding downstream of the weir during the low water period were exposed to catch-and-release mortality in July when the lower river opened to general fishing but remained closed to Chinook salmon fishing, including catch-and-release. During this period, it was thought that most of the fish in the lower river section were Chinook salmon. Chinook salmon accounted for 85% of the fish counted through the weir from 1 July through 15 July in 2007 and 2010. In 2010, the closed area downstream of the weir was extended from 300 feet to approximately 1,000 feet until 15 July to protect the highest concentration of holding Chinook salmon.

In 2010, the ratio of upstream counts to downstream counts was the same as that for 2008 (2.6:1) and higher than the 2003–2007 average (2.2:1), suggesting that the potential for negative bias in the sonar estimate (caused by emigrating kelts) was lower than average. However, it is likely some portion of the downstream-moving fish were steelhead because steelhead were netted during May and June, the sonar operation dates were 13 May to 8 June, and emigration timing of steelhead in 2009 had a midpoint on 7 June (Kerkvliet and Booz 2012).

The return of ocean-age-4 Chinook salmon in 2010 marked the final adult return from brood year (BY) 2004 and the first year that production could be fully assessed. Production from the record high 2004 escapement (12,016 fish, SE 283) was poor based on return per spawner (0.29; Tables 8 and 9). Based on spawner–recruit analysis, the population carrying capacity or the highest escapement for which the expected production equals the escapement (recruit-per-spawner equals 1) ranges from 11,080 to 14,550 Chinook salmon within an 80% credibility interval (Szarzi et al. 2007a). The 2004 escapement fell within this range, but the BY 2004 recruit-per-spawner estimate (0.29) suggests lower than average production. It is expected that with additional years of production data, the low production of BY 2004 can be more thoroughly evaluated.

Production from BY 2010 will be evaluated after adult Chinook salmon return in 2013–2016. A conservative estimate of the Chinook salmon smolt outmigration (75,052 smolt; 90% CI: 65,847–84,257) from BY 2010 has been provided by Anderson and Stillwater Sciences (2011). These data will be used in a future spawner–recruit analysis to define the productivity of the Anchor River stock more precisely.

The operation of the underwater video camera in August through September at the weir was an improvement over enumerating escapement using the live box because it was less disruptive to immigration timing, required less effort to operate, and provided sex information on all fish. The cooperative agreement between SF and USFWS will be continued in 2011. In 2011, the video system will be operated over the entire weir operation, and a live box will be incorporated so fish can also be captured when needed to collect biological samples.

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REFERENCES CITED

Anderson, J. L., and Stillwater Sciences. 2011. Chinook and coho salmon live history characteristics in the Anchor River watershed, Southcentral Alaska, 2010. U. S. Fish and Wildlife Service, Alaska Fisheries Data Series No. 2011-8, Soldotna, Alaska.

Bland, J. M., and D. G. Altman. 1986. Statistical methods for assessing agreement between two methods of clinical measurement. The Lancet 327(8476): 307-310.

Burwen, D. L., S. J. Fleischman, and J. D. Miller. 2007. Evaluation of a dual-frequency imaging sonar for estimating fish size in the Kenai River. Alaska Department of Fish and Game, Fishery Data Series No. 07 44, Anchorage. http://www.adfg.alaska.gov/FedAidPDFs/fds07-44.pdf

Burwen, D. L., S. J. Fleischman, and J. D. Miller. 2010. Accuracy and precision of manual fish length measurements from DIDSON sonar images. Transactions of the American Fisheries Society, 139:1306-1314.

Campana, S. E. 2001. Accuracy, precision and quality control in age determination, including a review of the use and abuse of age validation methods. Journal of Fish Biology 59:197-242.

Goodman, L. A. 1960. On the exact variance of products. Journal of the American Statistical Association 55:708-713.

Hammarstrom, S. L., L. Larson, M. Wenger, and J. Carlon. 1985. Kenai Peninsula Chinook and coho salmon studies. Alaska Department of Fish and Game. Federal Aid in Fish Restoration. Annual Performance Report, 1984-1985, Project F-9-17(26)G-II-L, Juneau. http://www.adfg.alaska.gov/FedAidPDFs/FREDf-9-17(26)G-II-L.pdf

Kerkvliet, C. M., and M. D. Booz. 2012. Anchor River Chinook and coho salmon escapement, 2009. Alaska Department of Fish and Game, Fishery Data Series No. 12-07, Anchorage. http://www.adfg.alaska.gov/FedAidpdfs/FDS12-07.pdf

Kerkvliet, C. M., M. D. Booz, and D. L. Burwen. 2012. Anchor River Chinook and coho salmon escapement, 2007–2008. Alaska Department of Fish and Game, Fishery Data Series No. 12-59, Anchorage. http://www.adfg.alaska.gov/FedAidpdfs/FDS12-59.pdf

Kerkvliet, C. M., M. D. Booz, B. J. Failor, and T. Blackmon. 2016. Sport fisheries in the Lower Cook Inlet Management Area, 2014–2016, with updates for 2013. Alaska Department of Fish and Game, Fishery Management Report No. 16-32, Anchorage. http://www.adfg.alaska.gov/FedAidPDFs/FMR16-32.pdf

Kerkvliet, C. M., and D. L. Burwen. 2010. Anchor River Chinook and coho salmon escapement project, 2005-2006. Alaska Department of Fish and Game, Fishery Data Series No. 10-26, Anchorage. http://www.adfg.alaska.gov/FedAidpdfs/Fds10-26.pdf

REFERENCES CITED (Continued)

Kerkvliet, C. M., D. L. Burwen, and R. N. Begich. 2008. Anchor River 2003 and 2004 Chinook salmon and 2004 coho salmon escapement. Alaska Department of Fish and Game, Fishery Data Series 08-06, Anchorage. http://www.adfg.alaska.gov/FedAidPDFs/fds08-06.pdf

Larson, L. L. 1990. Statistics for selected sport fisheries on the Anchor River, Alaska, during 1989 with emphasis on Dolly Varden char. Alaska Department of Fish and Game, Fishery Data Series No. 90-57, Anchorage. http://www.adfg.alaska.gov/FedAidPDFs/fds90-57.pdf

Larson, L. L. 1991. Statistics for Dolly Varden on the Anchor River, Alaska, during 1990. Alaska Department of Fish and Game, Fishery Data Series No. 91-13, Anchorage. http://www.adfg.alaska.gov/FedAidPDFs/fds91-13.pdf

Larson, L. L. 1992. Stock assessment of Dolly Varden on the Anchor River, Alaska during 1991. Alaska Department of Fish and Game, Fishery Data Series No. 92-14, Anchorage. http://www.adfg.alaska.gov/FedAidPDFs/fds92-14.pdf

Larson, L. L. 1993. Lower Kenai Peninsula Dolly Varden and steelhead trout studies during 1992. Alaska Department of Fish and Game, Fishery Data Series No. 93-54, Anchorage. http://www.adfg.alaska.gov/FedAidPDFs/fds93-54.pdf

Larson, L. L. 1994. Lower Kenai Peninsula Dolly Varden studies during 1993. Alaska Department of Fish and Game, Fishery Data Series No. 94-51, Anchorage. http://www.adfg.alaska.gov/FedAidPDFs/fds94-51.pdf

Larson, L. L. 1995. Lower Kenai Peninsula Dolly Varden studies during 1994. Alaska Department of Fish and Game, Fishery Data Series No. 95-44, Anchorage. http://www.adfg.alaska.gov/FedAidPDFs/fds95-44.pdf

Larson, L. L. 1997. Lower Kenai Peninsula Dolly Varden studies during 1995. Alaska Department of Fish and Game. Fishery Data Series No. 97-2, Anchorage. http://www.adfg.alaska.gov/FedAidPDFs/fds97-02.pdf

Larson, L. L., and D. T. Balland. 1989. Statistics for selected sport fisheries on the lower Kenai Peninsula, Alaska, during 1988 with emphasis on Dolly Varden char. Alaska Department of Fish and Game, Fishery Data Series No. 101, Juneau. http://www.adfg.alaska.gov/FedAidPDFs/fds-101.pdf

Larson, L. L., D. T. Balland, and S. Sonnichsen. 1988. Statistics for selected sport fisheries on the lower Kenai Peninsula, Alaska, during 1987 with emphasis on Dolly Varden char. Alaska Department of Fish and Game, Fishery Data Series No. 68, Juneau. http://www.adfg.alaska.gov/FedAidPDFs/fds-068.pdf

Mosher, K. H. 1969. Identification of Pacific salmon and steelhead trout by scale characteristics. U. S. Fish and Wildlife Service, Bureau of Commercial Fisheries, Circular 317.

Nelson, D. C. 1972. Population studies of anadromous fish populations - southwestern Kenai Peninsula and Kachemak Bay. Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Performance Report, 1971-1972, Project F-9-4, 13 (G-II-C), Juneau.

Nelson, D. C. 1994. Area management report for the recreational fisheries of the Kenai Peninsula, 1993. Alaska Department of Fish and Game, Fishery Management Report No. 94-07, Anchorage. http://www.adfg.alaska.gov/FedAidPDFs/fmr94-07.pdf

Nelson, D. C. 1995. Area management report for the recreational fisheries of the Kenai Peninsula, 1994. Alaska Department of Fish and Game, Fishery Management Report No. 95-04, Anchorage. http://www.adfg.alaska.gov/FedAidPDFs/fmr95-04.pdf

Shrout, P. E., and J. L. Fleiss. 1979. Intraclass correlations: Uses in assessing rater reliability. Psychological Bulletin 86(2): 420-428.

REFERENCES CITED (Continued)

Szarzi, N. J., and R. N. Begich. 2004. Recreational fisheries in the Lower Cook Inlet Management Area, 2001-2004: Fisheries under consideration by the Alaska Board of Fisheries 2004. Alaska Department of Fish and Game, Fishery Management Report No. 04-08, Anchorage. http://www.adfg.alaska.gov/FedAidPDFs/fmr04-08.pdf

Szarzi, N. J., S. J. Fleischman, R. A. Clark, and C. M. Kerkvliet. 2007a. Stock status and recommended escapement goal for Anchor River Chinook salmon. Alaska Department of Fish and Game, Fishery Manuscript No. 07-05, Anchorage. http://www.adfg.alaska.gov/FedAidpdfs/fms07-05.pdf

Szarzi, N. J., C. M. Kerkvliet, C. E. Stock, and M. D. Booz. 2007b. Recreational fisheries in the Lower Cook Inlet Management Area, 2005-2007, with updates for 2004. Alaska Department of Fish and Game, Fishery Management Report No. 07-55, Anchorage. http://www.adfg.alaska.gov/FedAidpdfs/fmr07-55.pdf

Szarzi, N. J., C. M. Kerkvliet, B. J. Failor, and M. D. Booz. 2010. Recreational fisheries in the Lower Cook Inlet Management Area, 2008-2010, with updates for 2007. Alaska Department of Fish and Game, Fishery Management Report No. 10-38, Anchorage. http://www.adfg.alaska.gov/FedAidpdfs/Fmr10-38.pdf

Welander, A. D. 1940. A study of the development of the scale of Chinook salmon Oncorhynchus tshawytscha. Master's thesis. University of Washington, Seattle.

Wolter, K. M. 1985. Introduction to variance estimation. Springer-Verlag, New York.

TABLES

Table 1.–Drainage characteristics of the north and south forks of Anchor River.

	Anchor River		
Drainage characteristics	North fork	South fork	Total
Watershed area (km^2)	181.5	405.3	586.8
Wetland area (km^2)	92.9	189.0	281.9
Percent wetland	51.2	46.6	48.0
Stream length (RKM)	149	352	501
Anadromous stream length (RKM)	90	176	266

Source: S. Baird, Research Analyst, Kachemak Bay Research Reserve in Homer, AK, unpublished data, 2006.

Note: “RKM” means river kilometers.

Table 2.–Statewide Harvest Survey estimates of angler effort and Chinook salmon harvest, catch, and number of days open to harvest for Anchor River Chinook salmon, 1977–2010.

	Chinook salmon						
	Harvest		Catch				
Year	Estimate	SE	Estimate	SE	Percent harvest [a]	Days open to harvest [b]	Harvest per day
1977	1,077	–	NA	–	NA	10	108
1978	2,109	–	NA	–	NA	12	176
1979	1,913	–	NA	–	NA	12	159
1980	605	–	NA	–	NA	12	50
1981	1,069	–	NA	–	NA	12	89
1982	718	–	NA	–	NA	12	60
1983	1,269	–	NA	–	NA	12	106
1984	998	–	NA	–	NA	12	83
1985	672	–	NA	–	NA	12	56
1986	1,098	–	NA	–	NA	12	92
1987	761	–	NA	–	NA	12	63
1988	976	–	NA	–	NA	14	70
1989	578	–	NA	–	ND	15	39
1990	1,479	–	4,119	–	36	15	99
1991	1,047	–	2,540	–	41	15	70
1992	1,685	–	4,506	–	37	15	112
1993	2,787	–	6,022	–	46	15	186
1994	2,478	–	3,890	–	64	15	165
1995	1,475	–	3,545	–	42	15	98
1996	1,483	201	6,594	1,883	22	15	99
1997	1,563	186	5,289	1072	30	15	104
1998	783	119	2,443	361	32	15	52
1999	1,409	192	6,903	1769	20	15	94
2000	1,730	193	5,200	797	33	15	115
2001	889	162	2,415	452	37	15	59
2002	1,047	192	4,103	854	26	12	87
2003	1,011	157	4,311	792	23	12	84
2004	1,561	198	5,561	1214	28	15	104
2005	1,432	233	5,028	1,386	28	15	95
2006	1,394	197	4,638	1,011	30	15	93
2007	2,081	326	9,792	1,812	21	15	139
2008	1,486	241	3,245	542	46	20	74
2009	737	212	2,296	518	32	12	61
2010	364	118	889	287	41	12	30
Average							
2003–2009	1,386	223	4,982	1,039	30	15	93
1977–2009	1,315	–	–	–	–	14	95

Source: Alaska Sport Fishing Survey database [Internet]. 1996– . Anchorage, AK: Alaska Department of Fish and Game, Division of Sport Fish (cited August 2015). Available from: http://www.adfg.alaska.gov/sf/sportfishingsurvey/.

Note: "Harvest" is fish kept, "catch" is fish harvested plus fish released, "ND" means no data, and "NA" means not applicable. The en dash means not calculated.

[a] Harvest per catch.

[b] Days open for Chinook salmon harvest (regulatory openings adjusted by emergency orders as needed).

Table 3.–Anchor River weir and DIDSON fish counts by species, 1987–1995 and 2003–2010.

				Fish counts						
Year	Project dates	Location (RKM) [a]	Method	Chinook salmon [b]	Dolly Varden [c]	Pink salmon [c]	Chum salmon	Sockeye salmon	Coho salmon [d]	Rainbow trout or steelhead [e]
1987 [f]	04 Jul–10 Sep	1.6	fixed picket weir	204	19,062	2,084	19	33	2,409	136
1988 [f]	03 Jul–05 Oct	1.6	fixed picket weir	245	14,935	777	24	30	2,805	878
1989 [f]	06 Jul–05 Nov	1.6	resistance board weir	95	11,384	4,729	165	212	20,187	769
1990 [f]	04 Jul–15 Aug	1.6	resistance board weir	144	10,427	355	17	39	190	3
1991 [f]	04 Jul–15 Aug	1.6	resistance board weir	39	18,002	1,757	9	46	13	5
1992 [f]	04 Jul–01 Oct	1.6	resistance board weir	129	10,051	992	39	174	4,596	1,261
1993 [f]	03 Jul–16 Aug	1.6	resistance board weir	90	8,262	1,019	12	71	290	1
1994 [f]	03 Jul–16 Aug	1.6	resistance board weir	111	17,259	723	2	61	420	1
1995 [f]	04 Jul–12 Aug	1.6	resistance board weir	112	10,994	1,094	4	73	725	10
2003 [g]	30 May–09 Jul	2.8	DIDSON	9,238 [h]	–	–	–	–	–	–
2004 [g]	15 May–13 Sep	2.8	DIDSON, resistance board weir	12,016 [h,i]	7,846	1,079	79	45	5,728	20
2005 [g]	13 May–09 Sep	2.8	DIDSON, resistance board weir	11,156 [h,i]	5,719	4,916	146	319	18,977	107
2006 [g, j]	15 May–24 Aug	2.8	DIDSON, resistance board weir	8,945 [h,i]	234	954	45	38	10,181 [j]	4
2007 [g]	14 May–12 Sep	2.8	DIDSON, resistance board weir	9,622 [h,i]	1,309	3,916	156	200	8,226	325
2008	13 May–11 Sep	2.8	DIDSON, resistance board weir	5,806 [h,i]	1,344	2,017	66	52	5,951	258
2009	12 May–11 Sep	2.8	resistance board weir	3,455	1,404	4,975	68	62	2,692	54
2010	13 May–29 Sep	2.8	DIDSON, resistance board weir	4,449 [h,i]	1,352	972	67	212	6,014	586

[a] River kilometers (RKM) from mouth of the Anchor River.

[b] Chinook salmon counts represent escapement because there is no harvest above the monitoring site. The run was only partially counted in 1987–1995 due to weir operation dates and location, and in 2003 due to weir operation dates.

[c] Incomplete Dolly Varden–pink salmon counts due to picket spacing of the weir (2004–2008) because smaller fish were able to pass through the weir pickets undetected.

[d] Incomplete coho salmon counts due to project operation dates (1991, 1993–1995, 2005–2006).

[e] Counts beginning July 1. Incomplete counts due to project operation dates and weir location (1987, 1990–1991, 1993–1995, and 2004–2009).

[f] Source for 1987: Larson et al. (1988); 1988: Larson and Balland (1989); 1989: Larson (1990); 1990: Larson (1991); 1991: Larson (1992); 1992: Larson (1993); 1993: Larson (1994); 1994: Larson (1995); 1995: Larson (1997), when escapement weir was located approximately 1.6 RKM from mouth.

[g] Source for 2003–2004: Kerkvliet et al. (2008); 2005–2006: Kerkvliet and Burwen (2010); 2007–2008: Kerkvliet et al. (2012); 2009: Kerkvliet and Booz (2012).

[h] All DIDSON images and the associated counts were assumed to be Chinook salmon.

[i] Chinook salmon estimates based on combined DIDSON and weir census. If DIDSON was operated in July, counts were apportioned between large fish (Chinook salmon) and small fish (Dolly Varden and pink salmon).

[j] No counts were collected from 19 to 21 August because the weir washed out due to flooding. The DIDSON was operated again from 22 to 24 August; an estimated 3,292 coho salmon were counted.

Table 4.–Anchor River Chinook salmon escapement, freshwater harvest, total run, and exploitation estimates, 2003–2010.

		Chinook salmon					
						Total run [a]	
		Escapement		Freshwater harvest			
Year	Project dates	Estimate	SE	Estimate	SE	Estimate	Exploitation rate (%) [b]
2003	30 May–09 Jul	9,238	0 [c]	1,011	157	10,249	9.9 [d]
2004	15 May–15 Sep	12,016	283 [e]	1,561	198	13,577	11.5
2005	13 May–09 Sep	11,156	229 [e]	1,432	233	12,588	11.4
2006	15 May–24 Aug	8,945	289 [e]	1,394	197	10,339	13.5
2007	14 May–12 Sep	9,622	238 [e]	2,081	326	11,703	17.8
2008	13 May–12 Sep	5,806	169 [e]	1,486	241	7,418	21.7
2009	12 May–11 Sep	3,455	0 [f]	737	212	4,192	17.6
2010	13 May–29 Sep	4,449	103 [e]	364	118	4,813	7.6
Averages							
2003–2008		9,464		1,515		10,979	13.8
2004–2007		10,435		1,617		12,052	13.4
2008–2010		4,570		904		5,474	16.5

Source: Harvest estimates from Alaska Sport Fishing Survey database [Internet]. 1996– . Anchorage, AK: Alaska Department of Fish and Game, Division of Sport Fish (cited August 2015). Available from: http://www.adfg.alaska.gov/sf/sportfishingsurvey/.

Note: Estimates of escapement for 2003–2008, 2010 may be low because of DIDSON bias due to emigrating steelhead kelts.

[a] "Total run" is escapement plus freshwater harvest; total does not account for the marine harvest.

[b] Percent of total run represented by harvest.

[c] The estimate is based on a census of all DIDSON files. Escapement was not fully assessed during the operation dates.

[d] Exploitation is conservative because escapement was not fully enumerated.

[e] The estimate is based on expanded DIDSON counts and weir counts.

[f] The run was censused over the entire run with weir counts.

Table 5.–Species composition in beach seine catches on the north and south forks of the Anchor River, 2010.

South fork			North fork		
Sample date	Chinook salmon	Steelhead	Sample dates	Chinook salmon	Steelhead
3 Jun	13	0	25 May	0	2
9 Jun	47	9	1 Jun	20	0
10 Jun	28	5			
Total	88	14		20	2

Table 6.–Between- and within-reader correlation analyses for DIDSON counts, Anchor River, 2010.

			Accumulated counts					
	Reader combination [a]	Number of files	First reader	Second reader	Kendall's tau	Intraclass correlation (r)	Intraclass 95% CI	Percent agreement
Between reader	1 and 3	33	37	35	0.93	0.94	0.888, 0.971	81.8
	2 and 3	40	112	111	0.84	0.98	0.958, 0.988	72.5
	Overall	73	644	669	0.88	0.98	0.961, 0.984	76.7
Within reader	1 and 1	36	49	40	0.81	0.85	0.730, 0.921	66.7
	2 and 2	37	73	72	0.77	0.97	0.951, 0.987	75.7
	Overall	73	361	333	0.81	0.94	0.904, 0.961	71.2

[a] Primary readers are 1 and 2; secondary reader is 3.

Table 7.–The estimated ocean age, sex, and length composition of the Anchor River Chinook salmon escapement, 2010.

		Composition by ocean age					
Sex	Parameter	1	2	3	4	Total	Composition by sex [a]
Female							
	Sample size [b]	0	14	79	11	104	127
	Estimated percent	0	5.1	27.9	4.2		37.8
	SE percent	0	1.4	2.9	1.3		2.8
	Estimated abundance	NA	227	1,241	187		1,682
	SE abundance	0	63	132	58		130
	Length samples	0	14	79	11		124
	Mean length (mm)	NA	648	779	804		762
	SE mean length (mm)	NA	21	6	15		7
Male							
	Sample size [b]	14	89	62	3	168	211
	Estimated percent	7.1	31.1	23.2	1.4		62.2
	SE percent	1.8	2.9	2.7	0.8		2.8
	Estimated abundance	316	1,384	1,032	62		2,767
	SE abundance	80	133	122	36		140
	Length samples	13	89	62	3		200
	Mean length (mm)	394	599	738	808		635
	SE mean length (mm)	18	12	14	75		11
All							
	Sample size [b,c]	14	103	142	14	272	338
	Estimated percent	7.0	36.1	51.3	5.6	100	
	SE percent	1.8	3.0	3.2	1.5		
	Estimated abundance	311	1,606	2,282	249		4,449
	SE abundance	80	139	152	67		269
	Length samples	13	103	142	14		324
	Mean length (mm)	394	607	758	800		683
	SE mean length (mm)	18	11	8	17		8

Note: "NA" means not applicable. Age, sex, and length-at-age compositions are based on weighted samples collected from nets on the south and north forks and the mainstem weir.

[a] In some cases where sex was determined, scales could not be read and age was not determined (thus total sample sizes for age and sex differ).

[b] Unweighted sample sizes by age class and sex.

[c] Sex was not determined for 1 ocean-age-3 fish and therefore sample size is 1 fish more than combined female and male sample sizes.

Table 8.–Anchor River Chinook salmon estimated escapement and freshwater harvest by ocean-age composition, 2003–2010.

	Escapement										Freshwater harvest					
											Number of fish					
			Percent by ocean age				Number by ocean age						Ocean Age			
Run Year	Estimate	SE	1	2	3	4	1	2	3	4	Estimate	SE	1	2	3	4
2003 [a]	9,238	0	5	23	58	14	471	2,125	5,340	1,275	1,011	157	52	233	584	140
2004	12,016	283	9	21	49	22	1,057	2,487	5,840	2,632	1,561	198	137	323	759	342
2005	11,156	229	5	24	52	19	558	2,666	5,823	2,108	1,432	233	72	342	748	271
2006	8,945	289	6	17	52	25	572	1,476	4,660	2,236	1,394	197	89	230	726	349
2007	9,622	238	1	22	53	24	48	2,116	5,138	2,319	2,081	326	10	458	1,111	502
2008	5,806	169	4	22	69	5	255	1,266	3,977	302	1,612	241	71	351	1,104	84
2009	3,455	0	8	51	37	4	269	1,766	1,268	152	737	212	57	377	270	32
2010	4,449	103	7	36	51	6	311	1,606	2,282	249	364	118	25	131	187	20
Average 2003–2010	8,086	164	6	27	53	15	665	2,174	5,130	1,575	1,274	210	64	306	686	217

[a] The 2003 estimate is based on a census of all DIDSON files. Escapement was not fully assessed during operation dates.

Table 9.–Anchor River Chinook salmon return per spawner by brood year, 2003–2010.

	Number of fish returning by brood year			
Brood year	Escapement by brood year	Freshwater harvest	Total return	Return per spawner
2003	6,817	1,684	8,501	0.92 [a]
2004	2,831	653	3,484	0.29
2005	–	–	–	–
2006	–	–	–	–
2007	–	–	–	–
2008	–	–	–	–
2009	–	–	–	–
2010	–	–	–	–

Note: Escapement by brood year could not be calculated for 2005–2010 because those brood years had not returned at the time of writing.

[a] Biased upward because escapement was not fully assessed.

FIGURES

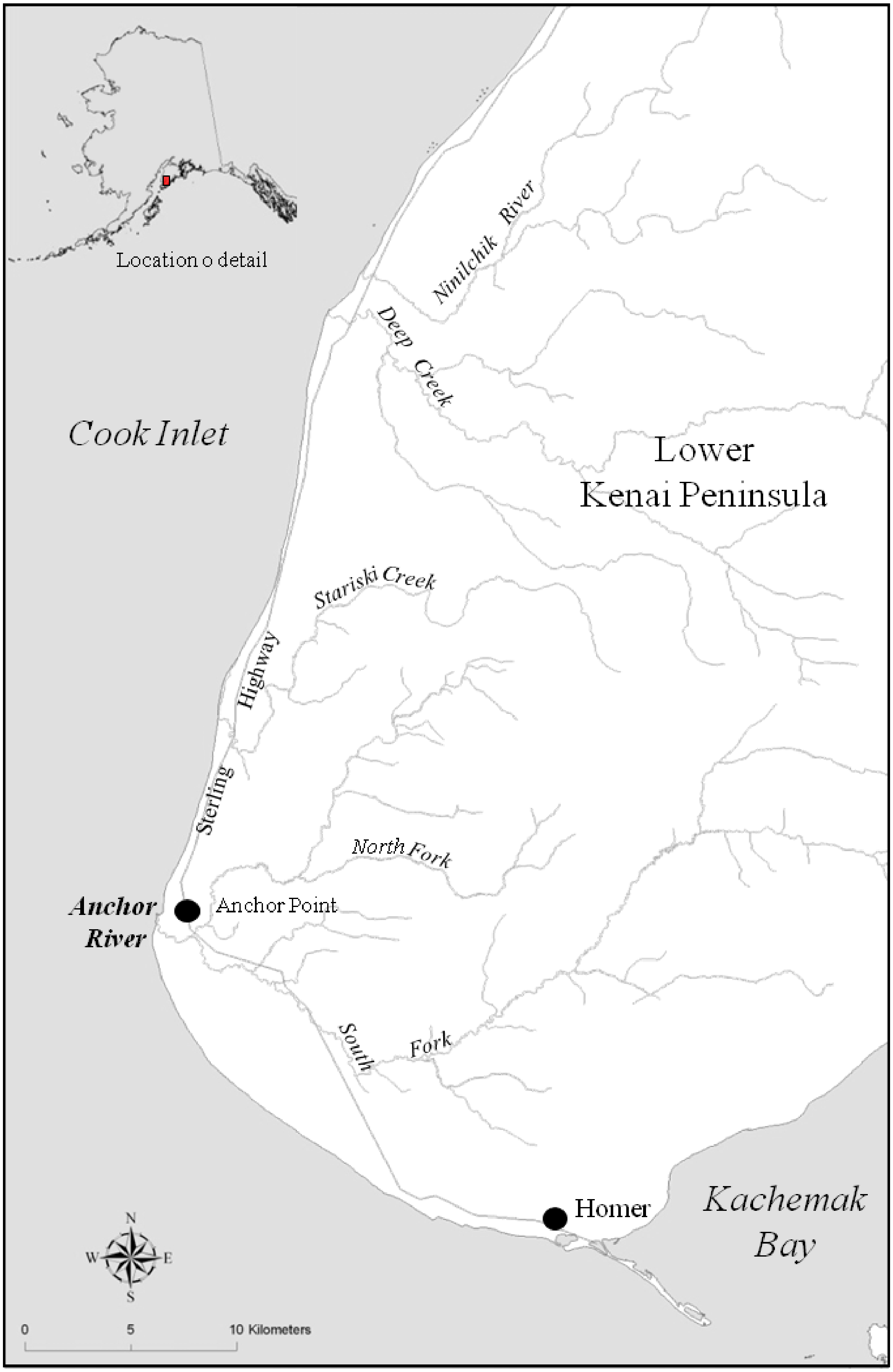

Figure 1.–Location of Anchor River and other roadside tributaries in the Lower Cook Inlet Management Area.

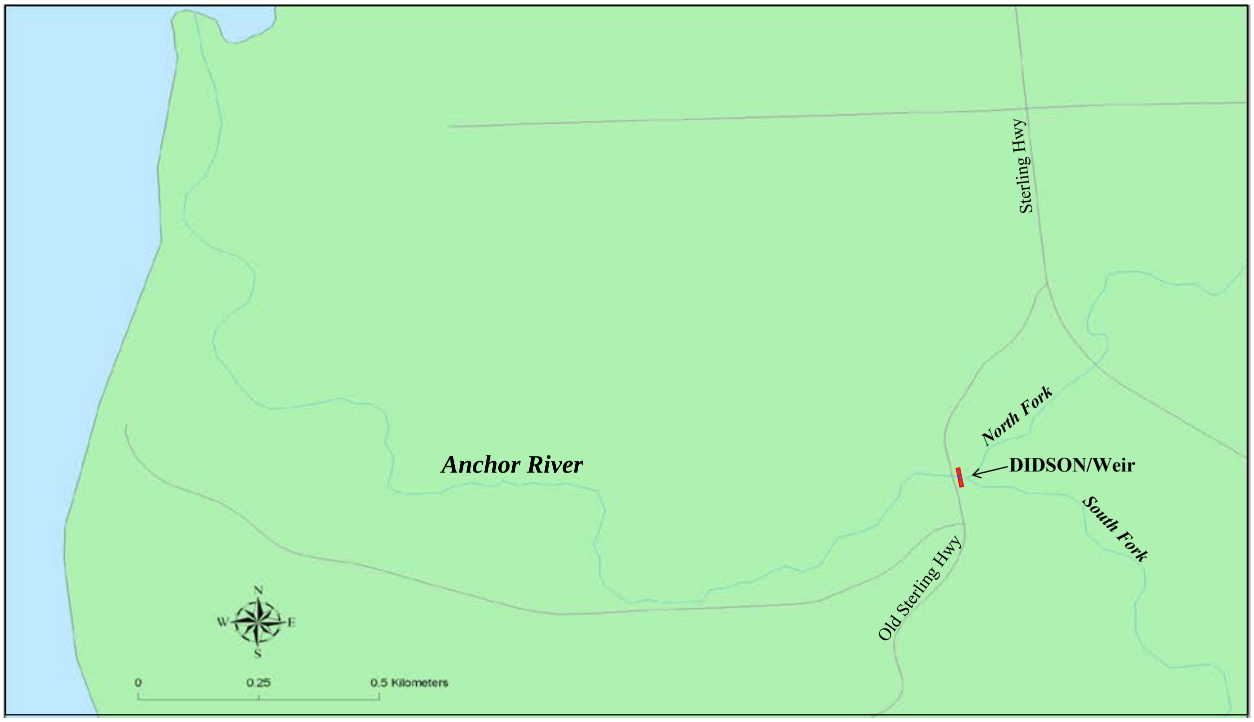

Figure 2.–Location of the mainstem DIDSON weir site on the Anchor River (lat 59.772233, long −151.835033).

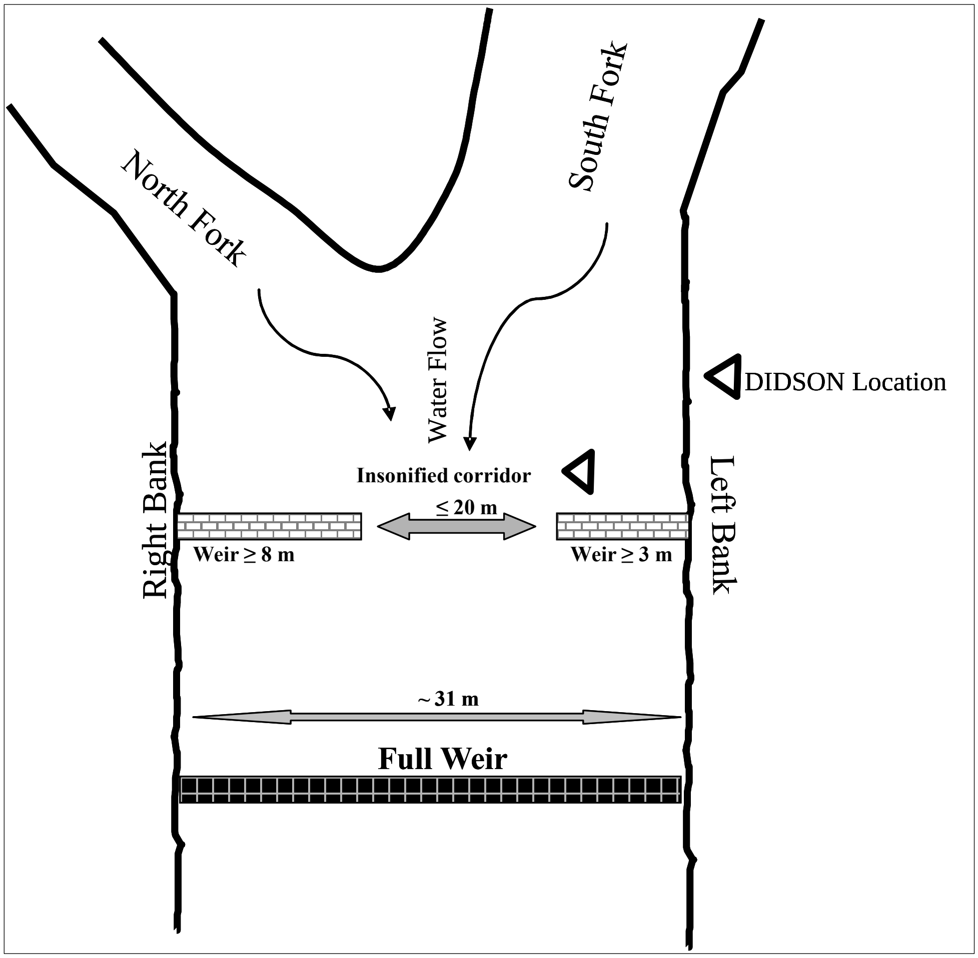

Figure 3.–Locations of the DIDSON, partial weirs, and full weir site on the mainstem of the Anchor River.

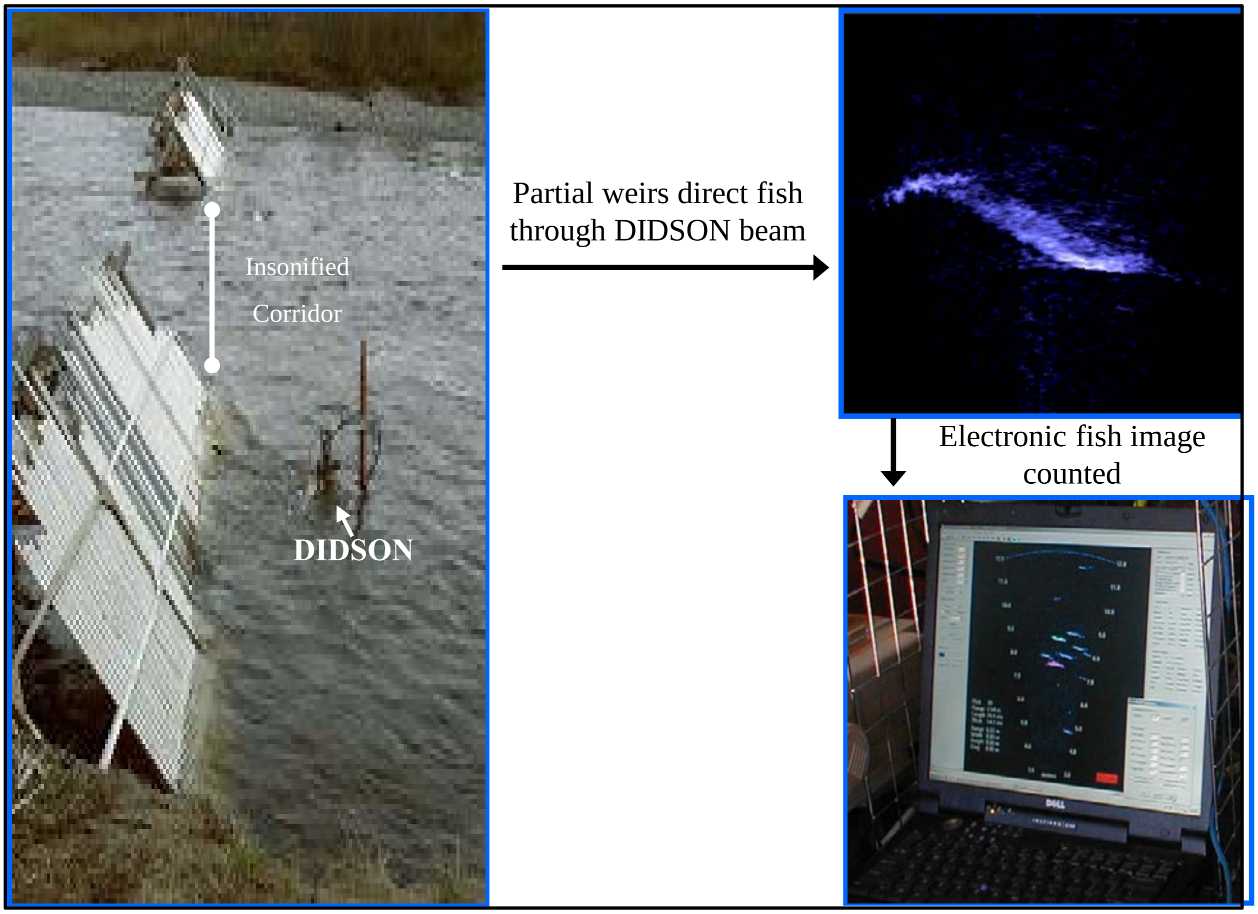

Figure 4.–DIDSON is used with partial weirs (left) to funnel fish through the DIDSON beam.

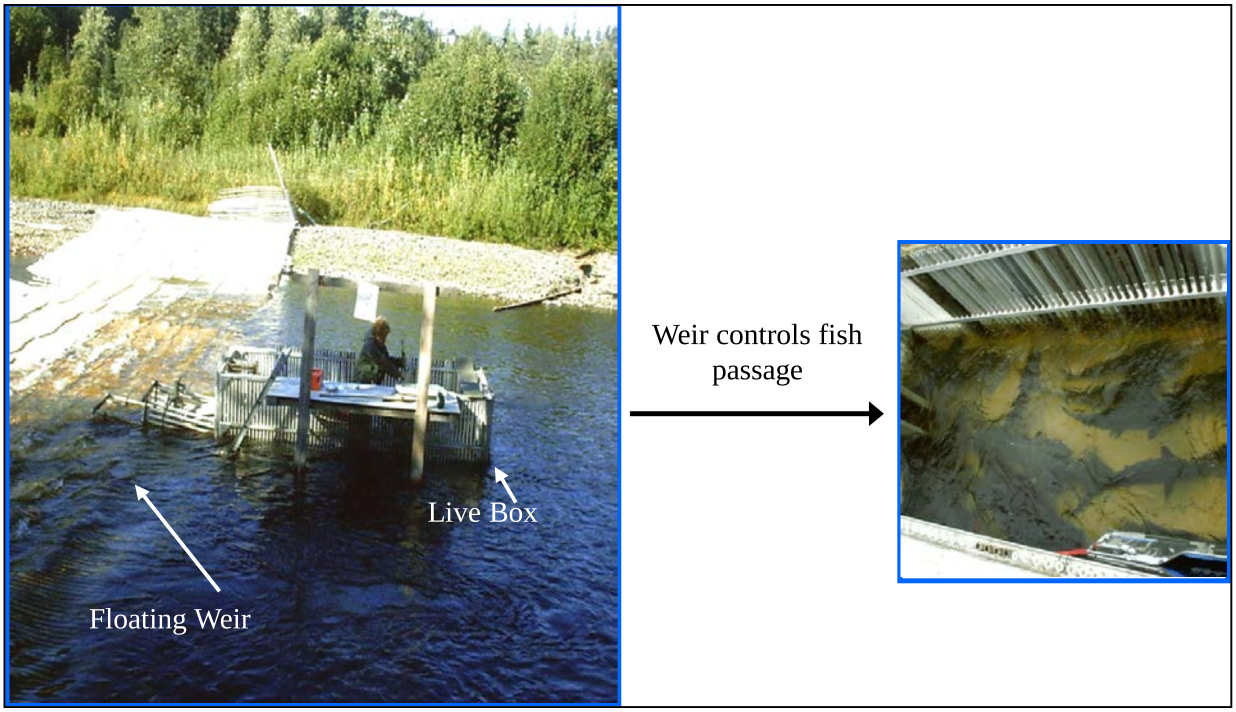

Figure 5.–Resistance board weir with mid-channel live box on the Anchor River.

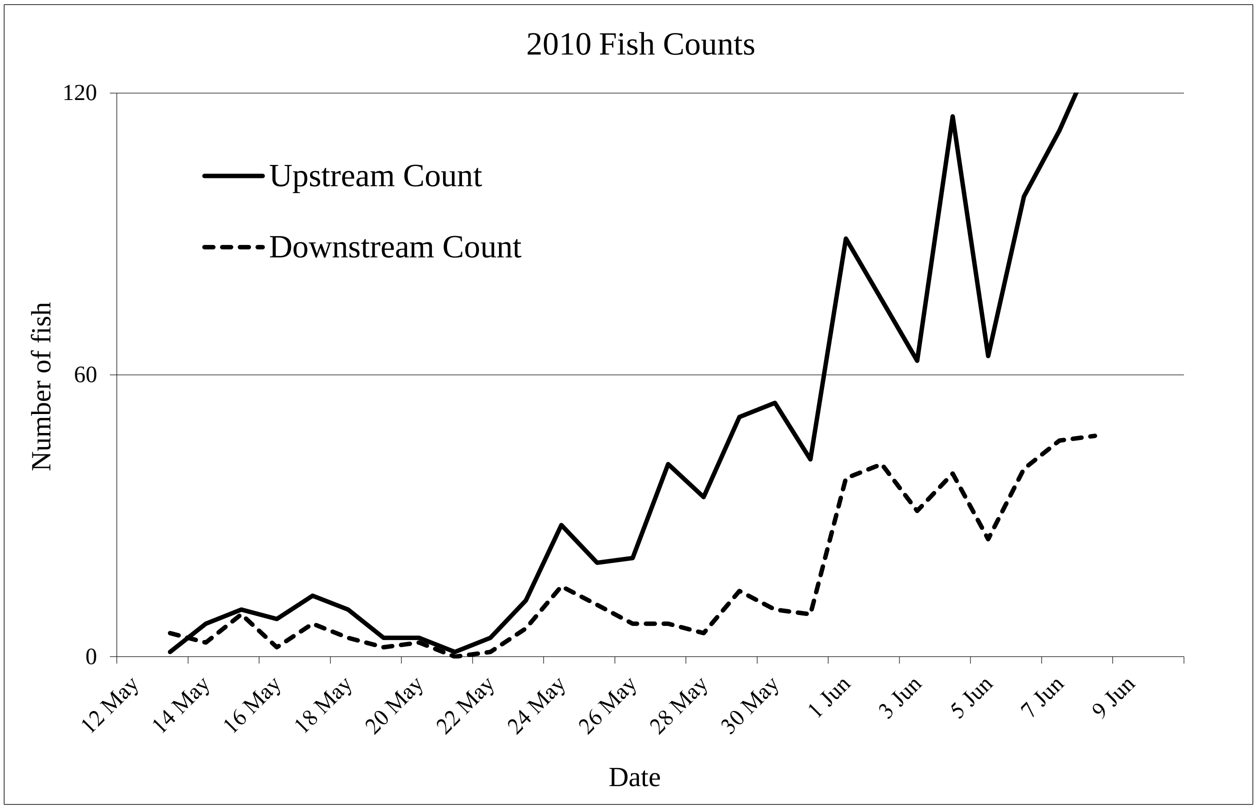

Figure 6.–Daily upstream and downstream counts based on DIDSON files, Anchor River, 2010.

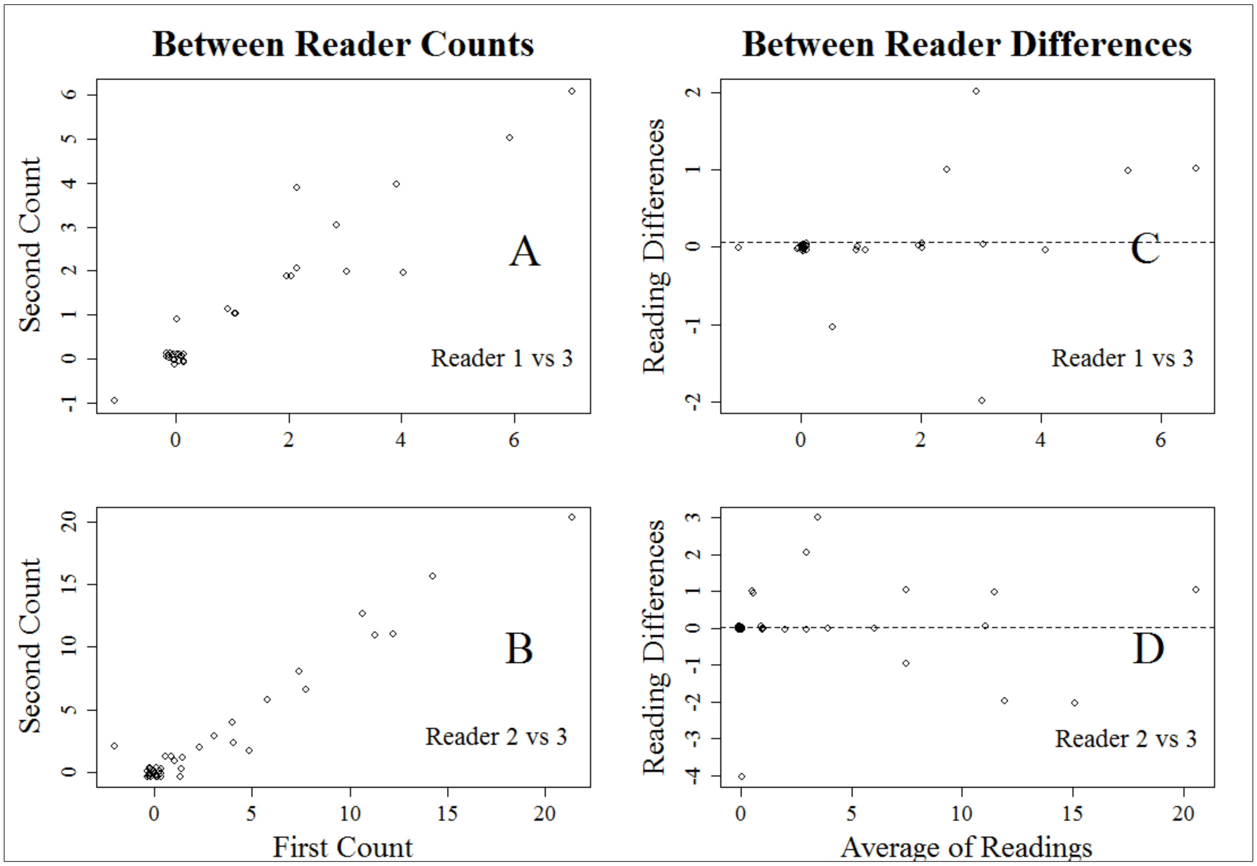

Figure 7.–Between-reader counts (plots A, B) and Tukey difference plots (plots C, D) for primary (readers 1 and 2; *x* axis counts for plots A and B) and secondary (reader 3; *y* axis counts for plots A and B) readers of 73 selected DIDSON files, Anchor River, 2010.

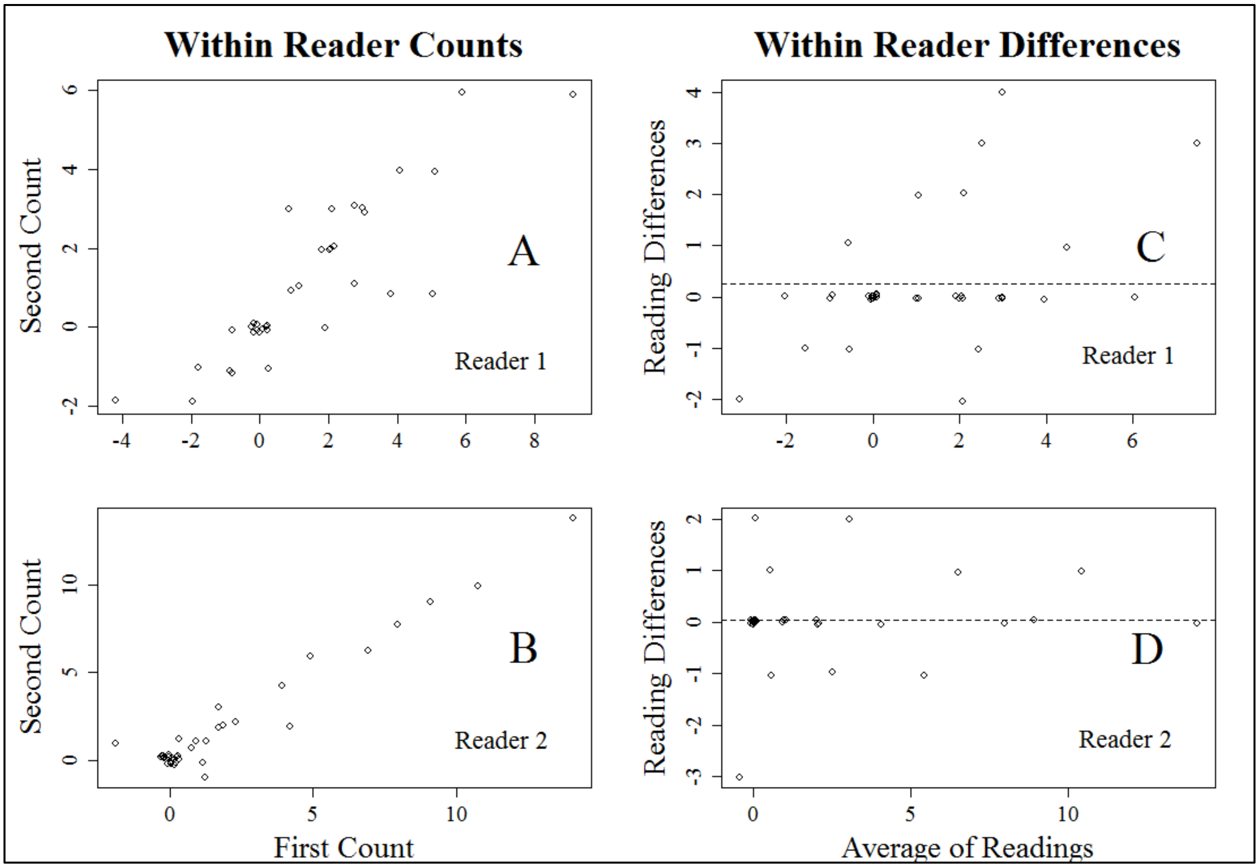

Figure 8.–Within-reader counts (A and B) and Tukey difference plots (C and D) for primary readers 1 and 2 of 73 selected DIDSON files, Anchor River, 2010.

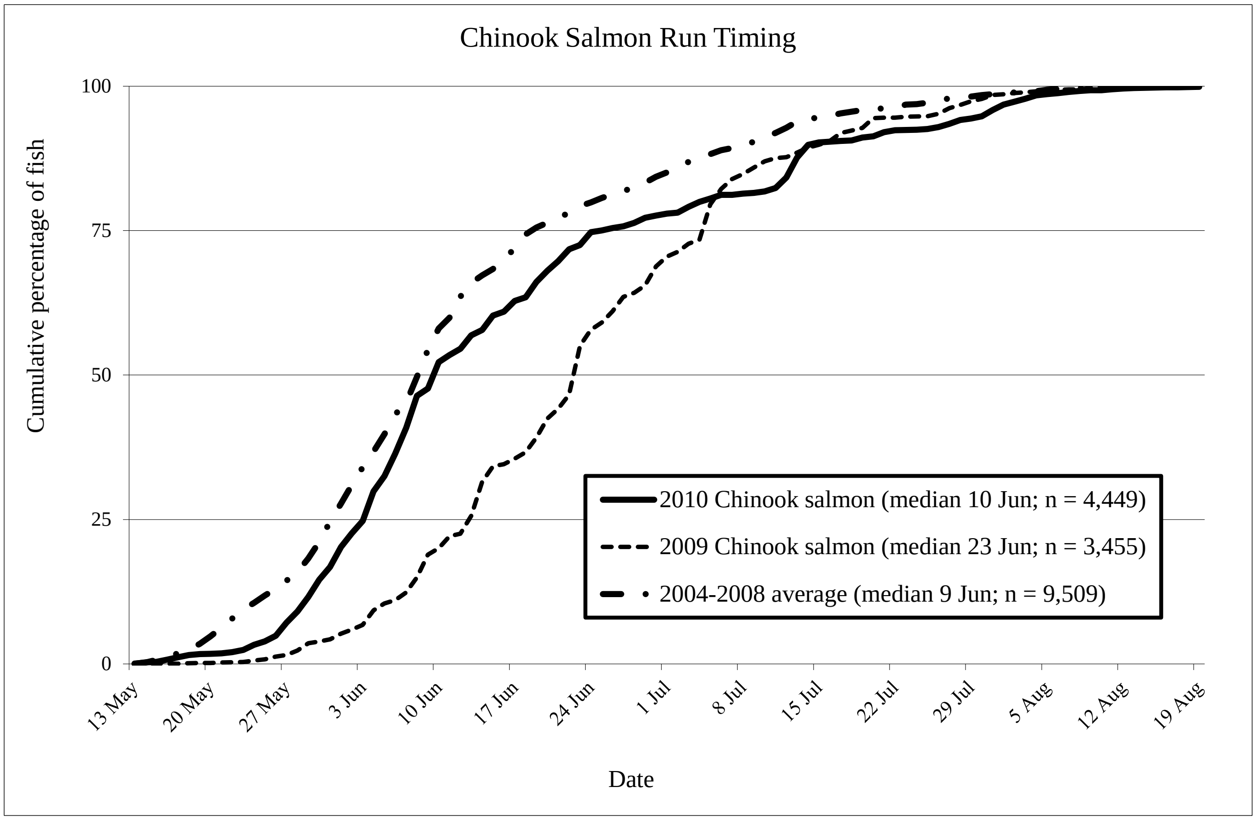

Figure 9.–Chinook salmon run timing of the 2010 immigration compared to 2009 and the recent average (2004–2009) at the Anchor River sonar-weir site.

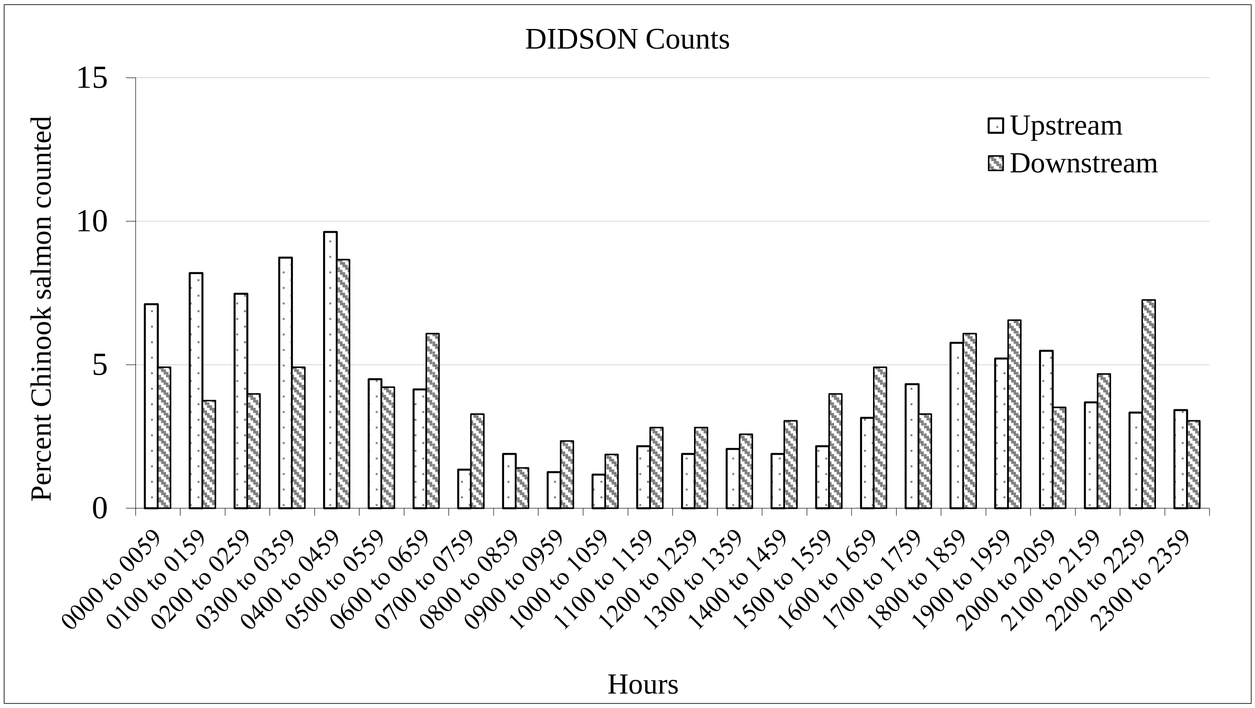

Figure 10.–Percent of upstream and downstream moving fish by hour (3 May to 8 June) based on 20-minute DIDSON counts, Anchor River, 2010.

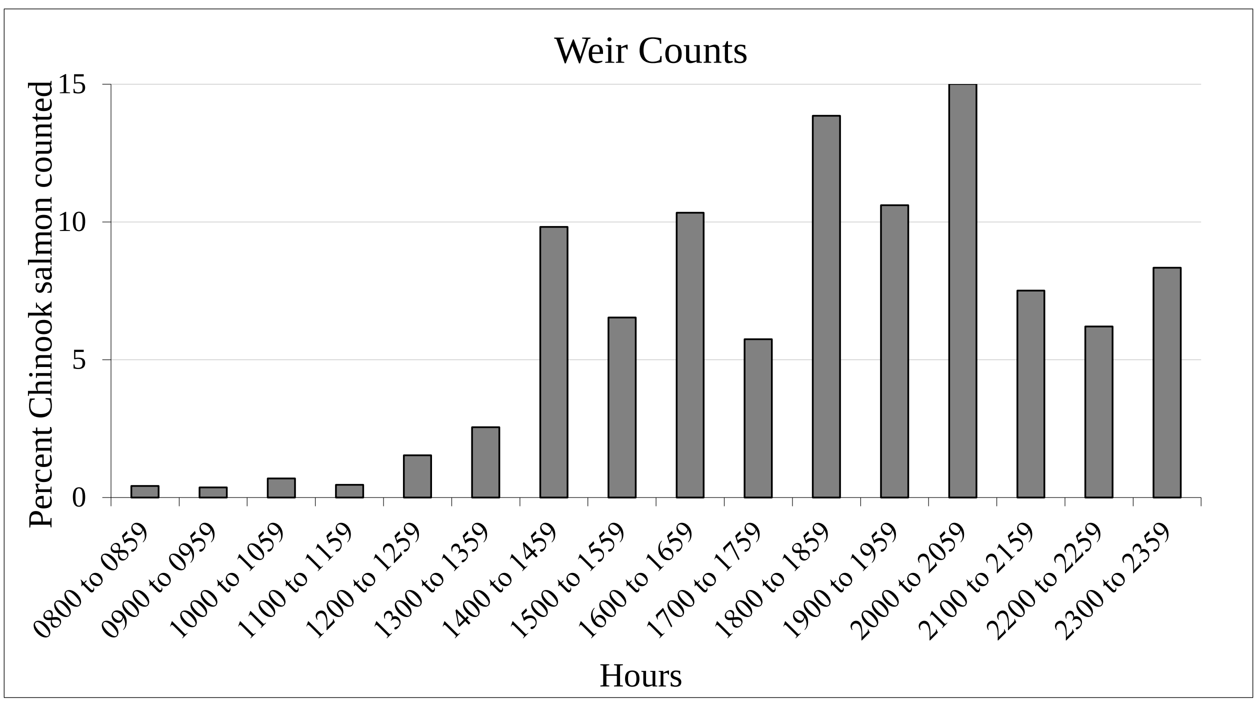

Figure 11.–Percent of Chinook salmon counted by hour (8 June to 1 August) based on ADFG south fork weir counts during 0800 hours to midnight, Anchor River, 2010.

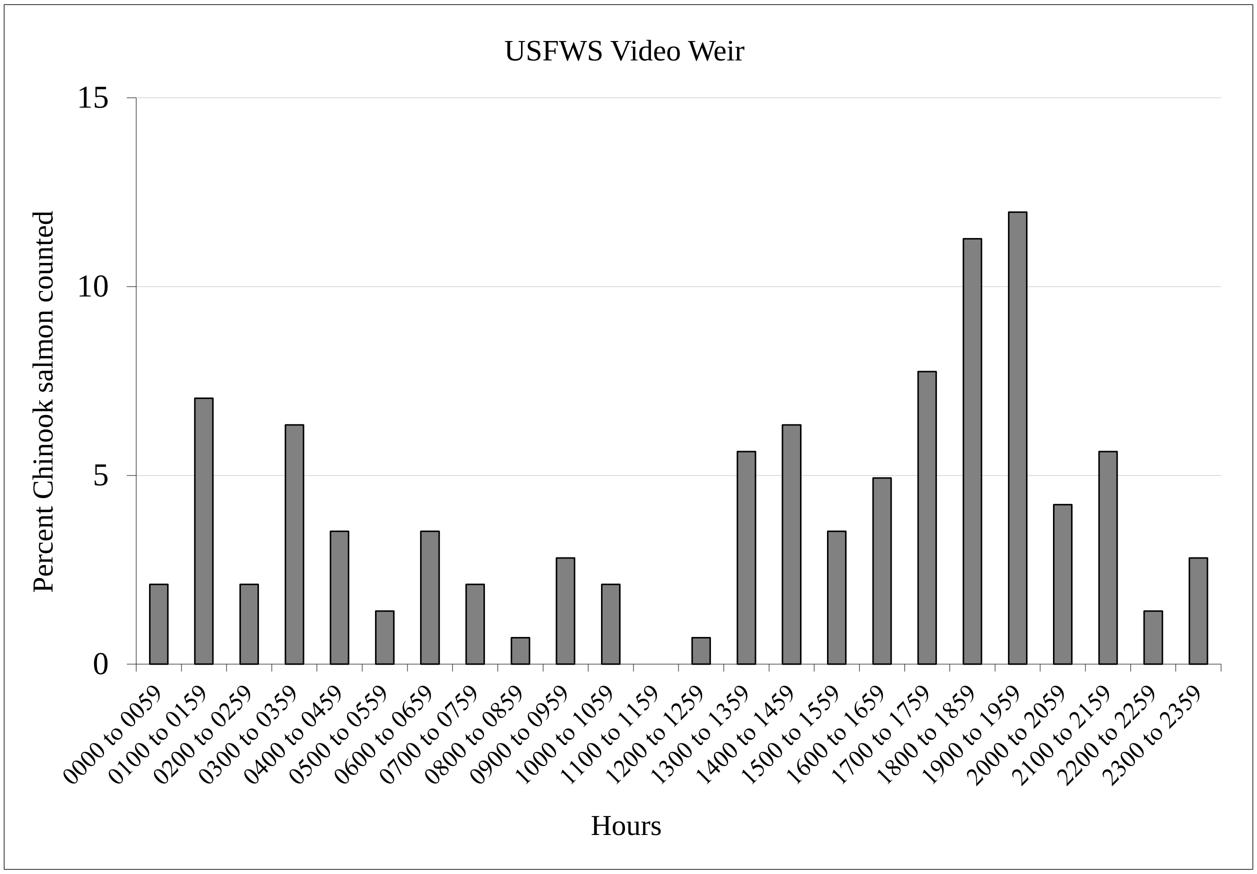

Figure 12.–Percent of Chinook salmon by hour (2 August to 29 September) based on USFWS Video weir during 0800 hours to midnight, Anchor River, 2010.

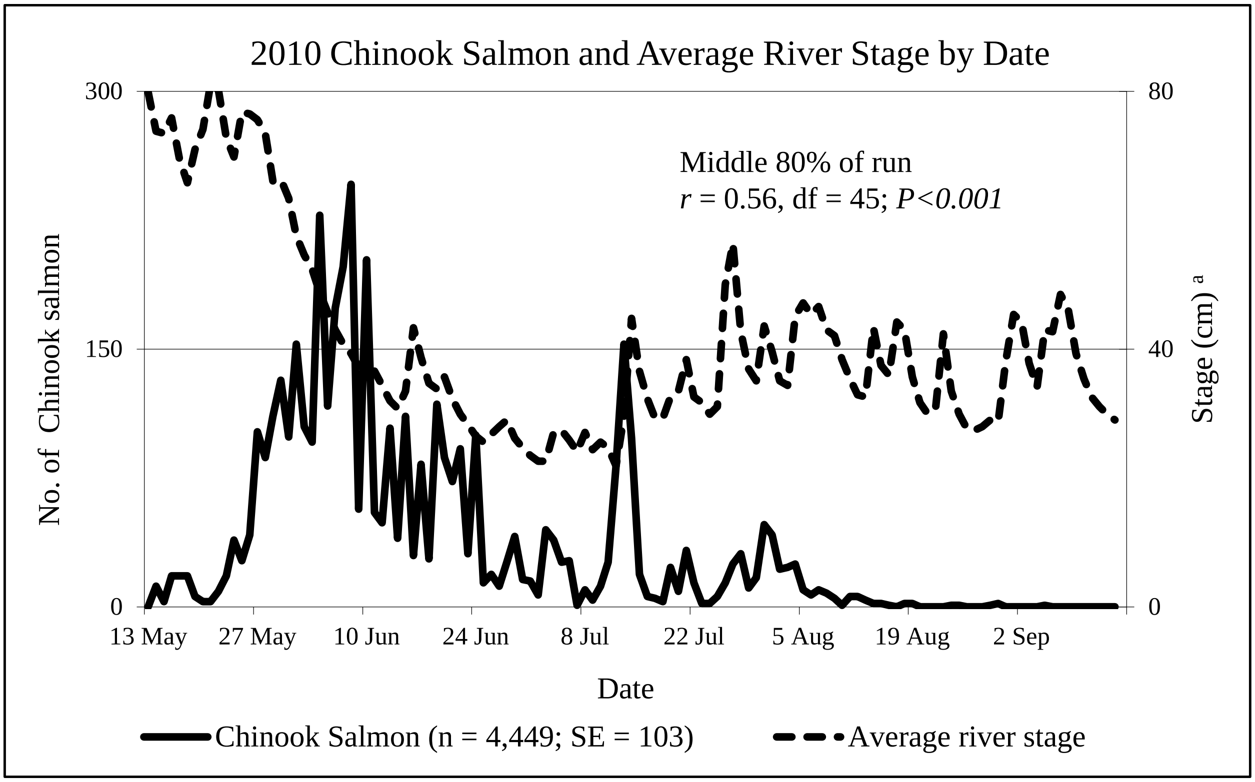

Figure 13.–Estimated daily counts of Chinook salmon at the sonar-weir site plotted against daily river stage averages by date, Anchor River, 2010.

[a] Stage data collected at gauge station USGS 15239900 located at approximately 11.4 RKM on the south fork, Anchor River.

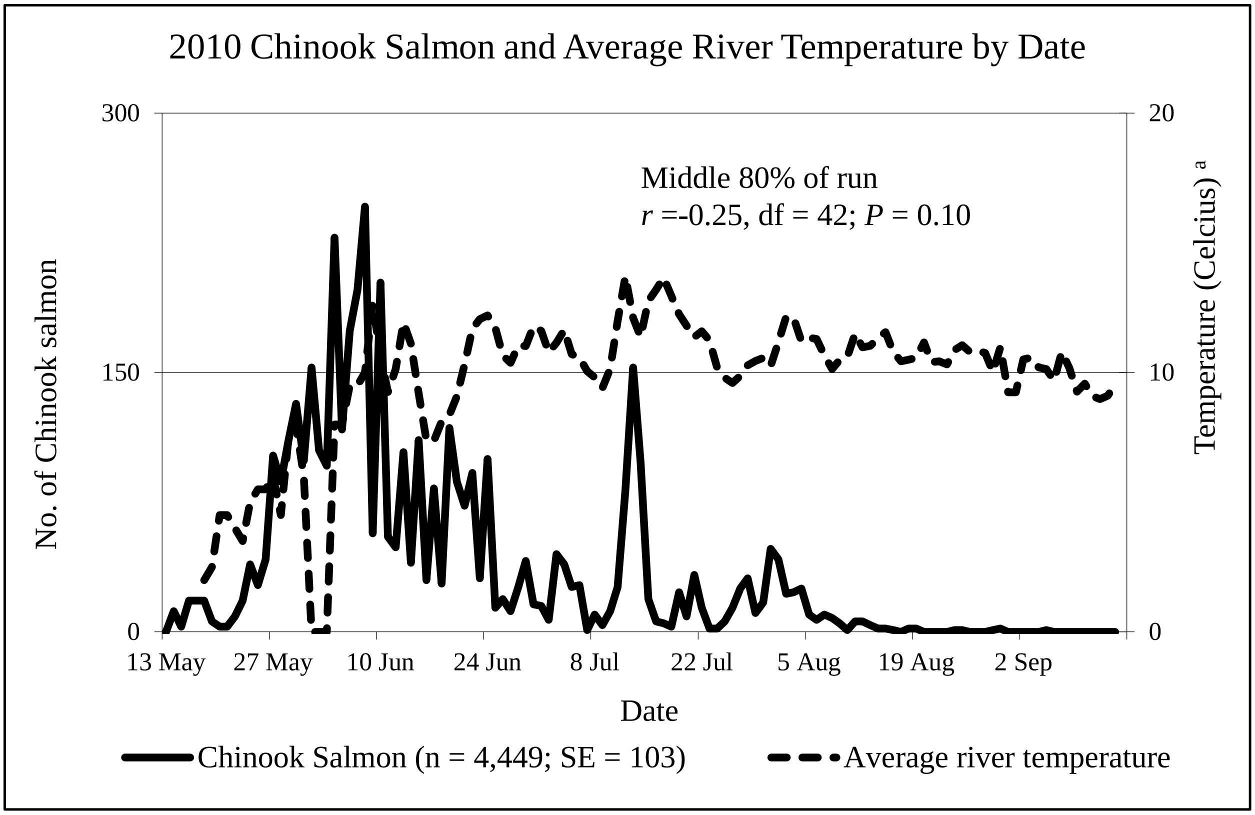

Figure 14.–Estimated daily counts of Chinook salmon at the sonar-weir site plotted against daily river temperature averages by date, Anchor River, 2010.

[a] Temperature data collected approximately 0.1 RKM downstream of the south and north forks confluence of the Anchor River.

APPENDIX A: MONITORING TIMELINES FOR ANCHOR RIVER CHINOOK SALMON

Appendix A1.–Timeline of escapement monitoring for Chinook salmon on the Anchor River, 1950–2010.

Year(s)	Escapement monitoring
1950s	Periodic fisheries investigations in the Anchor River were conducted by U.S. Fish and Wildlife Service. Chinook salmon escapement was monitored with weirs at various lower river locations on the North and South forks and mainstem. Aerial and foot surveys were also conducted.
1962–1969	Annual Chinook salmon escapement was estimated with a combination aerial and ground index survey. Surveys were conducted once annually over a standard length of river. Aerial surveys were done from a fixed-wing aircraft (Super Cub). Foot surveys were conducted within a subsection of the aerial survey from the Sterling Highway bridge upstream approximately 4 river kilometers (RKM) to forks. Where the foot survey was conducted, if the foot survey counts were greater than the aerial counts, the total aerial count was expanded by the difference. In 1966, no aerial surveys were conducted due to poor viewing conditions. Note: “standard length” and the location of the Sterling Highway bridge (old versus new) could not be determined.
1970–1974	The ground index subsection was expanded to approximately 8 RKM from Glanville lumber to forks. No aerial survey was conducted in 1970 or 1971. Note: “forks” is assumed to be North and South forks confluence.
1975–1982	Aerial surveys were conducted using rotary-wing aircraft to index Chinook salmon escapement. Surveys were conducted once annually over a standard section of the South Fork of the Anchor River. Foot surveys continued as before. Note: “forks” is assumed to be North and South forks confluence.
1983–1994	The index subsection for combined aerial and foot surveys was reduced back to approximately 4 RKM from Sterling Highway Bridge to forks. Note: “standard length” and the location of the Sterling Highway bridge (old versus new) could not be determined.
1995–2002	The foot survey was discontinued. Periodic foot surveys were conducted over additional stream reaches such as North Fork, Beaver Creek, and above forks. Aerial surveys continued.
2003	In addition to the aerial survey, the feasibility of using DIDSON sonar as an escapement monitoring tool was tested on the mainstem of the Anchor River just below the confluence of the North and South forks at RKM 2.8. DIDSON was only operated from 30 May through 9 July, not over the entire run.
2004	Chinook salmon escapement was monitored over the entire run at approximately RKM 2.8 through a combination of DIDSON during periods of high water and resistance board weir during periods of low water. A weir was operated on the North Fork to monitor the entire run at approximately RKM 6.2. Aerial surveys of the North Fork and South Fork index areas were used to compare index to total escapement estimates.
2005–2008	Chinook salmon escapement was monitored over the entire run at approximately RKM 2.8 through a combination of DIDSON during periods of high water and resistance board weir during periods of low water. Aerial surveys were continued through 2008 to compare index to total run estimates.
2009	Chinook salmon escapement was censused using a resistance board weir over the entire run at approximately RKM 2.8 because of low water levels. A foot survey of the historical index area was conducted from the new Sterling Highway Bridge (lat 59.746895, long −151.754319) to the confluence of the North and South Forks (lat 59.772253, long −151.834263).
2010	Chinook salmon escapement was monitored over the entire run at approximately RKM 2.8 through a combination of DIDSON during periods of high water and resistance board weir during periods of low water. Escapement monitoring in August and September was conducted through a cooperative agreement with USFWS. USFWS monitored escapement using the resistance board weir and an underwater video camera (Anderson and Stillwater Sciences 2011).

Appendix A2.–Timeline of sport harvest monitoring and escapement goals for Chinook salmon on the Anchor River, 1950–2010.

Year (s)	Sport harvest assessment
1950s	Periodic fisheries investigations in the Anchor River were conducted by U.S. Fish and Wildlife Service. Chinook salmon harvest was monitored through creel surveys.
1966–1977	Punch cards were used to enforce daily and seasonal limits (Hammarstrom et al. 1985).
1971–1977	Punch card returns were the primary source of harvest data. Effort was estimated by car counts each day at campgrounds and parking areas from 1971 to 1976.
1972–1986	Creel surveys were conducted at the Deep Creek access from 1972 to1986 and 1994 (Nelson 1994, 1995). A creel survey at the Anchor River–Whiskey Gulch access was conducted in 1986 (Nelson 1994).
1976–1983	Age composition of the Chinook salmon harvest was estimated for the Anchor River, Deep Creek, and Ninilchik River (Hammarstrom et al. 1985).
1977 to present	Statewide Harvest Surveys (SWHS) were conducted and produced annual estimates of total catch and harvest for Chinook salmon in the Anchor River.

Year (s)	Escapement goals
1993–1997	The first biological escapement goal (BEG) of 1,790 Chinook salmon was adopted in 1993. The BEG was the average of the expanded estimates from aerial and foot survey index counts conducted from 1966 to 1969 and from 1972 to 1991.
1998–2000	In 1998, the BEG was rescaled to a range of 1,050–2,200 Chinook salmon and was based on historical aerial survey counts and their relationship to sport harvest. The escapement range was approximated with a median aerial survey count of 1,211 Chinook salmon. The upper end of the range was the value that 20% of the annual aerial counts were above. The lower end was the value that 40% of the annual aerial counts were below (Szarzi and Begich 2004: page 22).
2001–2004	In 2001, the sustainable escapement goal (SEG) of 750 to 1500 Chinook salmon was adopted. The SEG was the 25th and 75th percentiles of the annual aerial counts from 1976 through 2000 (Szarzi and Begich 2004: page 22). During the Alaska Board of Fisheries (BOF) meeting in February 1999, in response to the guidelines established in the *Sustainable Salmon Fisheries Policy*, BOF designated Anchor River Chinook salmon as a stock of “management concern” defined in the policy as “a concern arising from a chronic inability, despite use of specific management measures, to maintain escapements for a salmon stock within the bounds of the SEG, BEG, [optimal escapement goal] OEG, or other specified management objectives for the fishery” (5 AAC 39.222 [f] [21]) (Szarzi and Begich 2004: page 25).
2005–2007	In 2005, the SEG was repealed and no new goal was adopted in anticipation that SF would collect sufficient escapement data with the DIDSON–weir project to recommend an escapement goal (Szarzi et al. 2007a).
2008	ADF&G adopted a lower bound SEG of 5,000 Chinook salmon. The SEG was based on a full probability spawner-recruit model that incorporated aerial survey data and SWHS harvest estimates from 1977 to 2007 and the total escapement estimates and age composition data collected from the DIDSON–weir project from 2003 to 2007 (Szarzi et al. 2007b).

Appendix A3.–Timeline of the freshwater fishing regulations and emergency orders (EOs) for Chinook salmon on the Anchor River, 1960–2010.

Closed areas for Chinook salmon

Year	Chinook salmon fishing regulations
1960–2010	Salmon fishing closed upstream of the junction of North and South forks.
1996–2010	The area above forks was closed to all fishing until August 1 to protect spawning salmon.

Recording requirements

Year	Chinook salmon fishing regulations
1966–1980	A Chinook salmon punch card was required by all anglers, including those under 16 years of age.
1981–2009	Anglers recorded Chinook salmon harvest on the back of a sport fishing license or harvest card.

Open season for Chinook salmon by regulation

Year	Chinook salmon fishing regulations
1960	May 7 to December 31.
1961	May 7 to July 1 only.
1962–1963	May 7 to July 8 only.
1964–1965	Closed
1966	May 28 to June 26 and limited to weekends and holidays or until 500 Chinook salmon 20 inches (in) or longer was attained among the Anchor River, Deep Creek, Ninilchik and Kenai Rivers.
1967	May 27 to June 11 opened continuously or until 500 Chinook salmon 20 in or longer was attained among the Anchor River, Deep Creek, Ninilchik and Kenai Rivers.
1968	May 25 to June 9 opened continuously or until 500 Chinook salmon 20 in or longer was attained among the Anchor River, Deep Creek, Ninilchik and Kenai Rivers. .
1969	May 24 to June 8 opened continuously or until 200 Chinook salmon 20 in or longer was attained among the Anchor River, Deep Creek, Ninilchik and Kenai Rivers.
1970	May 30 to June14 opened continuously or until 200 Chinook salmon 20 in or longer was attained among the Anchor River, Deep Creek, Ninilchik and Kenai Rivers.
1971	Beginning on the Memorial Day weekend for two consecutive 2-day weekends (Saturday and Sunday). Quota eliminated.
1972	Beginning on the Memorial Day weekend for two consecutive 2-day weekends.
1973–1975	Beginning on the Memorial Day weekend for three consecutive 2-day weekends.
1976–1977	Beginning on the Memorial Day weekend for four consecutive 2-day weekends.
1978–1988	Beginning on the Memorial Day weekend for four consecutive 3-day weekends (weekends include Monday).
1989–2001	Beginning on the Memorial Day weekend for five consecutive 3-day weekends (weekends include Monday).
2002–2004	Beginning on the Memorial Day weekend for four consecutive 3-day weekends (weekends include Monday).
2005-2007	Beginning on the 3-day weekend before the Memorial Day weekend and four consecutive 3-day weekends.
2008–2010	Beginning on the 3-day weekend before the Memorial Day weekend and four consecutive 3-day weekends. Also the Wednesdays following each weekend opening.

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Bag, possession, and season limits	
Year	Chinook salmon fishing regulations
1960	Bag and possession limit: 3 salmon over 16 inches in length, of which not more than 2 could be Chinook salmon 20 inches or more in length.
1961–1962	Bag and possession limit: 3 salmon over 20 inches in length, of which not more than 1 could be Chinook salmon 20 inches or more in length.
1963	Bag and possession limit: salmon 16 inches or more in length; 6 coho salmon; 3 pink, chum or sockeye salmon; or 1 Chinook salmon.
1964–1965	Closed.
1966–1978	Bag and possession limit: 1 Chinook salmon 20 inches or more in length.
	Bag and possession limit: 10 Chinook salmon less than 20 inches long.
	Season limit: 2 Chinook salmon 20 inches or more in length.
1979–1985	Bag and possession limit: 1 Chinook salmon 20 inches or more in length.
	Bag and possession limit: 10 Chinook salmon less than 20 inches long.
	Season limit: 5 Chinook salmon 20 inches or more in length.
1986–1995	Bag limit: 1 Chinook salmon 16 inches or more in length.
	Bag and possession limit: 10 Chinook salmon less than 16 inches long.
	Season limit: 5 Chinook salmon 16 inches or more in length.
1996–1998	Bag limit: 1 Chinook salmon 16 inches or more in length.
	Bag and possession limit: 10 Chinook salmon less than 16 inches long.
	Season limit: 2 Chinook salmon 16 inches or more in length from Deep Creek or the Anchor River combined.
	After harvesting a Chinook salmon 16 inches or more in length from Deep Creek or the Anchor River, an angler may not fish in either drainage for the rest of that day.
1996–1998	Bag limit: 1 Chinook salmon 16 inches or more in length.
	Bag and possession limit: 10 Chinook salmon less than 16 inches long.
	Season limit: 2 Chinook salmon 16 inches or more in length from Deep Creek or the Anchor River combined.
	After harvesting a Chinook salmon 16 inches or more in length from Deep Creek or the Anchor River, an angler may not fish in either drainage for the rest of that day.
1999–2007	Bag limit: 1 Chinook salmon 20 inches or more in length.
	Bag and possession limit: 10 Chinook salmon less than 20 inches long.
	Season limit: 2 Chinook salmon 20 inches or more in length from Deep Creek or the Anchor River combined.
	After harvesting a Chinook salmon 20 inches or more in length from Deep Creek or the Anchor River an angler may not fish in either drainage for the rest of that day.
2008–2010	Bag limit: 1 Chinook salmon 20 inches or more in length.
	Bag and possession limit: 10 Chinook salmon less than 20 inches length.
	Season limit: 5 Chinook salmon 20 inches or more in length.

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Emergency orders (EOs)	
Year	Chinook salmon fishing regulations
1971	EO extended the Chinook salmon fishery on Anchor River and Deep Creek an additional 2-day weekend due to low catches (Nelson 1972)
1972	EO extended the Chinook salmon fishery on Anchor River and Deep Creek an additional 2-day weekend due to low catches (Nelson 1972).
1988	EO 2-KS-1-04-88 extended the Chinook salmon fishery on Anchor River and Deep Creek an additional weekend. Highly turbid river conditions early in the season depressed angler success rates and managers' expectations (D. C. Nelson, unpublished[6]).
2004	EO 2-KS-7-07-04 opened the Anchor River Chinook salmon fishery from 0000 hours on Saturday, 26 June through 2359 hours on 28 June from the mouth of the Anchor River to 600 ft downstream of the confluence of the North and South forks. Bag limit: 1 Chinook salmon per day.
2009	EO 2-KS-7-08-09 closed the Anchor River drainage from its mouth upstream to the North and South forks to fishing and increased the closed area in the salt waters of Cook Inlet at the mouth of the Anchor River from 2 miles to 4 miles beginning 0001 hours on Saturday, 6 June through 2359 hours on Tuesday, 30 June.
2010	EO 2-KS-7-10-10 prohibited the use of bait in the Anchor River, Deep Creek, and Ninilchik River drainages and increased the closed area in the salt waters of Cook Inlet at the mouth of the Anchor River from 1 to 2 miles north and south of the Anchor River mouth and 1 mile offshore beginning 0001 hours on Saturday, 5 June through 2359 hours on Wednesday, 30 June.
2010	EO 2-KS-7-15-10 prohibited the retention of Chinook salmon in the Anchor River drainage from its mouth upstream to the junction of the North and South forks beginning 0001 hours on Saturday, 12 June through 2359 hours on Wednesday, 30 June. Chinook salmon may not be possessed or retained; Chinook salmon caught may not be removed from the water and must be released immediately. EO 2-KS-7-10-10 which prohibited the use of bait in the Anchor River, Deep Creek, and Ninilchik River drainages remained in effect.
2010	EO 2-KS-7-28-10 closed the salt waters of Cook Inlet at the mouth of the Anchor River to all sport fishing from 2 miles north and south of the Anchor River mouth and 1 mile offshore beginning 0001 hours on Thursday, 1 July through 2359 hours on Saturday, 31 July.
2010	EO 2-KS-7-36-10 rescinded EO 2-KS-7-28-10 issued 29 June 2010. Effective 0001 hours on Tuesday, 13 July, the salt waters of Cook Inlet at the mouth of the Anchor River from 2 miles north and south of the Anchor River mouth and 1 mile offshore were open to all sport fishing.

[6] Nelson, D. C. *Unpublished*. A review of Alaska's Kenai Peninsula east side beach recreational razor clam (Siliqua patula, Dixon) fishery, 1965-1980. Alaska Department of Fish and Game, Division of Sport Fish, Soldotna, Alaska.

APPENDIX B: DIDSON SPECIFICATIONS AND SETTINGS

Appendix B1.–DIDSON specifications for 2010.

Dual frequency identification sonar (DIDSON) operates at 2 discrete frequencies: a higher frequency that produces higher resolution images and a lower frequency that can detect targets at farther ranges but at a reduced image resolution. The standard model DIDSON used on the Anchor River operates at 1.8 MHz for close range observations (less than 15 m) and 1.0 MHz for observations from 15 m up to 30 m with overall beam dimensions that are 29° in the horizontal axis and 12° in the vertical axis. The ultra-high resolution large lens sets a smaller vertical beam pattern (approximately 3°). The combined concentration of horizontal and vertical beam widths increased the returned signal from a given target by 10 dB. At high frequency (1.8 MHz), image resolution is enhanced because the image is formed using 96 beams, each 0.3° wide, compared to low frequency (1.0 MHz), which forms the image using only 48 beams that are 0.6° wide. Image resolution is also influenced by the data collection “window length;” i.e., range interval sampled, which is implemented in discrete lengths of 2.5 m, 5.0 m, 10.0 m, 20.0 m, and 40.0 m. Because the DIDSON image is composed of 512 samples (pixels) in range, images with shorter window lengths are better resolved (down-range resolution equals window length divided by 512). Consequently images collected at smaller window lengths (2.5 m, 5.0 m, and 10.0 m) and high frequency (1.8 MHz) are preferable to their counterparts (20 m and 40 m at 1.0 MHz).

Appendix B2.–DIDSON settings used to collect escapement data for 2010.

In 2010 for most of the season (13 May at 1700 hours to 21 May at 0900 hours and 23 May at 1500 hours to 8 June at 1200 hours), the DIDSON was programmed to collect data using low frequency and a 20 m window length in three 20-minute files for each hour. During high turbidity conditions (21 May at 1000 hours through 23 May at 1400 hours), the DIDSON software was programmed to collect data at two 10 m range strata in addition to a single 20 m range stratum as follows:

1) Lower quality images were collected during the first 20-minute time period of each hour from 0 m to 20 m (full range; 0 m represents the sonar lens surface). Images recorded with a 20 m window length have half the resolution of those collected with a 10 m window length. Data were collected using the following software parameters: frames/sec = X, receiver gain = 40, window start = 0.83 m, window length = 20 m, and focus = auto.
2) Higher quality images were collected during the second 20-minute period at high frequency from 0 m to 10 m (near range). Images recorded for the near range appear better resolved due to the shorter window length. Data were collected using the following software parameters: total frames = 8328, receiver gain = 40, window start = 0.83 m, window length = 10.0 m, and focus = 5.85.
3) Higher quality images were collected during the third 20-minute period at low frequency from 10 m to 20 m (long range). Images recorded for the long range appear larger and easier to see because the window length is small. Data were collected using the following software parameters: total frames = 8368, receiver gain = 40, window start = 10.0 m, window length = 10.0 m, and focus = 15.13.

From 21 May at 1000 hours through 23 May at 1400 hours, the counts from Range 2 (0–10 m) and Range 3 (10–20 m) were summed to provide a surrogate for a full 20-minute count of the entire span of the river. If one of the Range 2 or Range 3 counts was incomplete or missing, then the count for Range 1 (0–20 m) was used.

On 19 May, counts from 0800 hours through 1200 hours were lost because of a computer malfunction and the estimated counts were interpolated.

APPENDIX C: DAILY ESCAPEMENT COUNTS AT THE ANCHOR RIVER SONAR-WEIR SITE, 2010

Appendix C1.–Daily and cumulative (cum.) escapement of Chinook salmon; Dolly Varden; and pink, chum, sockeye, and coho salmon; and steelhead trout counted at the Anchor River sonar-weir site, 2010.

	Chinook count[a]			Dolly Varden count			Pink count			Chum count			Sockeye count			Coho count			Steelhead count		
Date	Daily	Cum.	%	Daily	Cum.	%	Daily	Cum.	%	Daily	Cum.	%	Daily	Cum.	%	Daily	Cum.	%	Daily	Cum.	%
13 May [b]	0	0	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
14 May	12	12	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
15 May	3	15	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
16 May	18	33	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
17 May	18	51	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
18 May	18	69	2	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
19 May	6	75	2	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
20 May	3	78	2	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
21 May	3	81	2	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
22 May	9	90	2	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
23 May	18	108	2	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
24 May	39	147	3	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
25 May	27	174	4	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
26 May	42	216	5	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
27 May	102	318	7	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
28 May	87	405	9	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
29 May	111	516	12	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
30 May	132	648	15	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
31 May	99	747	17	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
1 Jun	153	900	20	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
2 Jun	105	1,005	23	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
3 Jun	96	1,101	25	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
4 Jun	228	1,329	30	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
5 Jun	117	1,446	33	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
6 Jun	174	1,620	36	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
7 Jun	198	1,818	41	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
8 Jun [c]	246	2,064	46	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9 Jun	57	2,121	48	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10 Jun	202	2,323	52	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11 Jun	55	2,378	53	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

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	Chinook count[a]			Dolly Varden count			Pink count			Chum count			Sockeye count			Coho count			Steelhead count		
Date	Daily	Cum.	%	Daily	Cum.	%	Daily	Cum.	%	Daily	Cum.	%	Daily	Cum.	%	Daily	Cum.	%	Daily	Cum.	%
12 Jun	49	2,427	55	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13 Jun	104	2,531	57	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14 Jun	40	2,571	58	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15 Jun	111	2,682	60	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16 Jun	30	2,712	61	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
17 Jun	83	2,795	63	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18 Jun	28	2,823	63	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19 Jun	118	2,941	66	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20 Jun	87	3,028	68	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21 Jun	73	3,101	70	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22 Jun	92	3,193	72	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23 Jun	31	3,224	72	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24 Jun	100	3,324	75	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0
25 Jun	14	3,338	75	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	3	1
26 Jun	19	3,357	75	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	6	1
27 Jun	12	3,369	76	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	7	1
28 Jun	26	3,395	76	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	7	1
29 Jun	41	3,436	77	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	7	1
30 Jun	16	3,452	78	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	7	1
1 Jul	15	3,467	78	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	7	1
2 Jul	7	3,474	78	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	7	1
3 Jul	45	3,519	79	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	7	1
4 Jul	39	3,558	80	2	2	0	1	2	0	1	1	1	0	0	0	0	0	0	1	8	1
5 Jul	26	3,584	81	3	5	0	0	2	0	0	1	1	0	0	0	0	0	0	0	8	1
6 Jul	27	3,611	81	7	12	1	0	2	0	0	1	1	0	0	0	0	0	0	0	8	1
7 Jul	1	3,612	81	0	12	1	0	2	0	0	1	1	0	0	0	0	0	0	0	8	1
8 Jul	10	3,622	81	1	13	1	2	4	0	1	2	3	0	0	0	0	0	0	0	8	1
9 Jul	4	3,626	82	0	13	1	0	4	0	0	2	3	0	0	0	0	0	0	0	8	1
10 Jul	12	3,638	82	2	15	1	0	4	0	0	2	3	0	0	0	0	0	0	0	8	1
11 Jul	26	3,664	82	30	45	3	1	5	1	0	2	3	0	0	0	0	0	0	0	8	1
12 Jul	82	3,746	84	16	61	5	1	6	1	0	2	3	0	0	0	0	0	0	0	8	1

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	Chinook count[a]			Dolly Varden count			Pink count			Chum count			Sockeye count			Coho count			Steelhead count		
Date	Daily	Cum.	%	Daily	Cum.	%	Daily	Cum.	%	Daily	Cum.	%	Daily	Cum.	%	Daily	Cum.	%	Daily	Cum.	%
13 Jul	153	3,899	88	15	76	6	5	11	1	3	5	7	1	1	0	0	0	0	0	8	1
14 Jul	98	3,997	90	0	76	6	1	12	1	0	5	7	0	1	0	0	0	0	1	9	2
15 Jul	19	4,016	90	2	78	6	2	14	1	0	5	7	1	2	1	0	0	0	0	9	2
16 Jul	6	4,022	90	0	78	6	1	15	2	0	5	7	1	3	1	0	0	0	0	9	2
17 Jul	5	4,027	91	12	90	7	0	15	2	0	5	7	0	3	1	0	0	0	0	9	2
18 Jul	3	4,030	91	0	90	7	1	16	2	0	5	7	0	3	1	0	0	0	0	9	2
19 Jul	23	4,053	91	3	93	7	3	19	2	0	5	7	0	3	1	0	0	0	0	9	2
20 Jul	9	4,062	91	1	94	7	1	20	2	0	5	7	0	3	1	0	0	0	0	9	2
21 Jul	33	4,095	92	3	97	7	1	21	2	2	7	10	1	4	2	2	2	0	0	9	2
22 Jul	14	4,109	92	2	99	7	0	21	2	1	8	12	0	4	2	0	2	0	0	9	2
23 Jul	2	4,111	92	0	99	7	0	21	2	0	8	12	0	4	2	0	2	0	0	9	2
24 Jul	2	4,113	92	0	99	7	0	21	2	1	9	13	0	4	2	0	2	0	0	9	2
25 Jul	6	4,119	93	0	99	7	1	22	2	2	11	16	2	6	3	3	5	0	0	9	2
26 Jul	14	4,133	93	1	100	7	2	24	2	0	11	16	2	8	4	2	7	0	0	9	2
27 Jul	25	4,158	93	17	117	9	3	27	3	1	12	18	0	8	4	5	12	0	0	9	2
28 Jul	31	4,189	94	2	119	9	4	31	3	0	12	18	1	9	4	4	16	0	0	9	2
29 Jul	11	4,200	94	0	119	9	0	31	3	0	12	18	0	9	4	4	20	0	0	9	2
30 Jul	17	4,217	95	0	119	9	3	34	3	0	12	18	1	10	5	5	25	0	0	9	2
31 Jul	48	4,265	96	1	120	9	2	36	4	2	14	21	1	11	5	16	41	1	0	9	2
1 Aug	42	4,307	97	0	120	9	2	38	4	0	14	21	0	11	5	10	51	1	0	9	2
2 Aug	22	4,329	97	17	137	10	7	45	5	0	14	21	1	12	6	16	67	1	1	10	2
3 Aug	23	4,352	98	37	174	13	10	55	6	1	15	22	3	15	7	37	104	2	0	10	2
4 Aug	25	4,377	98	27	201	15	58	113	12	2	17	25	7	22	10	98	202	3	0	10	2
5 Aug	10	4,387	99	32	233	17	15	128	13	1	18	27	2	24	11	25	227	4	0	10	2
6 Aug	7	4,394	99	11	244	18	19	147	15	3	21	31	6	30	14	58	285	5	0	10	2
7 Aug	10	4,404	99	4	248	18	17	164	17	3	24	36	6	36	17	36	321	5	0	10	2
8 Aug	8	4,412	99	3	251	19	11	175	18	0	24	36	5	41	19	40	361	6	0	10	2
9 Aug	5	4,417	99	8	259	19	20	195	20	1	25	37	3	44	21	90	451	7	1	11	2
10 Aug	1	4,418	99	50	309	23	35	230	24	0	25	37	1	45	21	108	559	9	1	12	2
11 Aug	6	4,424	99	64	373	28	17	247	25	1	26	39	6	51	24	104	663	11	2	14	2
12 Aug	6	4,430	100	46	419	31	26	273	28	1	27	40	10	61	29	275	938	16	0	14	2

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	Chinook count[a]			Dolly Varden count			Pink count			Chum count			Sockeye count			Coho count			Steelhead count		
Date	Daily	Cum.	%	Daily	Cum.	%	Daily	Cum.	%	Daily	Cum.	%	Daily	Cum.	%	Daily	Cum.	%	Daily	Cum.	%
13 Aug	4	4,434	100	33	452	33	32	305	31	2	29	43	11	72	34	153	1,091	18	1	15	3
14 Aug	2	4,436	100	20	472	35	90	395	41	9	38	57	11	83	39	684	1,775	30	3	18	3
15 Aug	2	4,438	100	19	491	36	23	418	43	5	43	64	6	89	42	152	1,927	32	2	20	3
16 Aug	1	4,439	100	0	491	36	14	432	44	1	44	66	10	99	47	139	2,066	34	0	20	3
17 Aug	0	4,439	100	12	503	37	46	478	49	4	48	72	20	119	56	438	2,504	42	2	22	4
18 Aug	2	4,441	100	17	520	38	15	493	51	1	49	73	10	129	61	77	2,581	43	1	23	4
19 Aug	2	4,443	100	9	529	39	15	508	52	3	52	78	8	137	65	60	2,641	44	2	25	4
20 Aug	0	4,443	100	28	557	41	12	520	53	4	56	84	5	142	67	106	2,747	46	2	27	5
21 Aug	0	4,443	100	17	574	42	15	535	55	0	56	84	3	145	68	196	2,943	49	4	31	5
22 Aug	0	4,443	100	13	587	43	20	555	57	1	57	85	7	152	72	119	3,062	51	0	31	5
23 Aug	0	4,443	100	46	633	47	47	602	62	0	57	85	2	154	73	735	3,797	63	7	38	6
24 Aug	1	4,444	100	19	652	48	8	610	63	0	57	85	4	158	75	103	3,900	65	4	42	7
25 Aug	1	4,445	100	28	680	50	12	622	64	0	57	85	7	165	78	130	4,030	67	5	47	8
26 Aug	0	4,445	100	20	700	52	21	643	66	0	57	85	2	167	79	107	4,137	69	3	50	8
27 Aug	0	4,445	100	12	712	53	14	657	68	1	58	87	7	174	82	57	4,194	70	2	52	9
28 Aug	0	4,445	100	11	723	53	11	668	69	0	58	87	1	175	83	84	4,278	71	2	54	9
29 Aug	1	4,446	100	9	732	54	21	689	71	0	58	87	2	177	83	141	4,419	73	1	55	9
30 Aug	2	4,448	100	11	743	55	18	707	73	2	60	90	2	179	84	38	4,457	74	4	59	10
31 Aug	0	4,448	100	8	751	56	34	741	76	1	61	91	2	181	85	212	4,669	78	7	66	11
1 Sep	0	4,448	100	15	766	57	39	780	80	1	62	93	4	185	87	453	5,122	85	19	85	14
2 Sep	0	4,448	100	1	767	57	10	790	81	0	62	93	3	188	89	43	5,165	86	15	100	17
3 Sep	0	4,448	100	9	776	57	19	809	83	2	64	96	1	189	89	46	5,211	87	10	110	19
4 Sep	0	4,448	100	9	785	58	19	828	85	0	64	96	5	194	92	22	5,233	87	13	123	21
5 Sep	1	4,449	100	10	795	59	49	877	90	0	64	96	3	197	93	278	5,511	92	21	144	24
6 Sep	0	4,449	100	18	813	60	17	894	92	2	66	99	0	197	93	51	5,562	92	14	158	27
7 Sep	0	4,449	100	22	835	62	17	911	94	0	66	99	1	198	93	160	5,722	95	26	184	31
8 Sep	0	4,449	100	18	853	63	20	931	96	0	66	99	3	201	95	57	5,779	96	30	214	36
9 Sep	0	4,449	100	69	922	68	6	937	96	0	66	99	0	201	95	19	5,798	96	48	262	44
10 Sep	0	4,449	100	17	939	69	9	946	97	0	66	99	2	203	96	25	5,823	97	27	289	49
11 Sep	0	4,449	100	33	972	72	8	954	98	0	66	99	1	204	96	27	5,850	97	19	308	52
12 Sep	0	4,449	100	24	996	74	5	959	99	0	66	99	1	205	97	35	5,885	98	40	348	59

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	Chinook count[a]			Dolly Varden count			Pink count			Chum count			Sockeye count			Coho count			Steelhead count		
Date	D.	Cum.	%	D.	Cum.	%	Daily	Cum.	%	Daily	Cum.	%	Daily	Cum.	%	Daily	Cum.	%	Daily	Cum.	%
13 Sep	0	4,449	100	19	1,015	75	4	963	99	0	66	99	0	205	97	26	5,911	98	41	389	66
14 Sep	0	4,449	100	20	1,035	77	0	963	99	0	66	99	3	208	98	9	5,920	98	19	408	69
15 Sep	0	4,449	100	17	1,052	78	2	965	99	0	66	99	0	208	98	13	5,933	99	13	421	71
16 Sep	0	4,449	100	12	1,064	79	0	965	99	0	66	99	0	208	98	10	5,943	99	5	426	72
17 Sep	0	4,449	100	9	1,073	79	2	967	99	0	66	99	0	208	98	21	5,964	99	19	445	75
18 Sep	0	4,449	100	8	1,081	80	0	967	99	0	66	99	0	208	98	8	5,972	99	16	461	78
19 Sep	0	4,449	100	18	1,099	81	2	969	100	0	66	99	0	208	98	7	5,979	99	8	469	79
20 Sep	0	4,449	100	11	1,110	82	1	970	100	0	66	99	0	208	98	6	5,985	100	6	475	80
21 Sep	0	4,449	100	27	1,137	84	1	971	100	0	66	99	0	208	98	10	5,995	100	18	493	83
22 Sep	0	4,449	100	26	1,163	86	0	971	100	0	66	99	1	209	99	7	6,002	100	11	504	85
23 Sep	0	4,449	100	69	1,232	91	1	972	100	0	66	99	2	211	100	7	6,009	100	25	529	89
24 Sep	0	4,449	100	23	1,255	93	0	972	100	1	67	100	1	212	100	0	6,009	100	18	547	92
25 Sep	0	4,449	100	31	1,286	95	0	972	100	0	67	100	0	212	100	3	6,012	100	27	574	97
26 Sep	0	4,449	100	29	1,315	97	0	972	100	0	67	100	0	212	100	0	6,012	100	3	577	97
27 Sep	0	4,449	100	26	1,341	99	0	972	100	0	67	100	0	212	100	1	6,013	100	8	585	99
28 Sep	0	4,449	100	11	1,352	100	0	972	100	0	67	100	0	212	100	1	6,014	100	5	590	99
29 Sep	0	4,449	100	0	1,352	100	0	972	100	0	67	100	0	212	100	1	6,014	100	3	593	100

Note: En dash denotes no information.

[a] Escapement estimated from DIDSON expanded counts (2,064, SE 103) from 13 May to 8 June and a census through the weir (2,385) from 8 June to 29 September.

[b] Expanded sonar count of 12 fish culled to reduce negative bias and daily count set to 0 fish.

[c] Daily Chinook salmon estimate (246 fish) was based on expanded DIDSON net count. No Chinook salmon were passed through the weir live box.

APPENDIX D: COUNTS BASED ON DIDSON FILES

Appendix D1.–Daily upstream, downstream, net, and expanded counts based on DIDSON files, Anchor River, 2010.

Date	Upstream	Downstream	Net Count [a]	Expanded [b]
13 May	1	5	-4	0 [c]
14 May	7	3	4	12
15 May	10	9	1	3
16 May	8	2	6	18
17 May	13	7	6	18
18 May	10	4	6	18
19 May	4	2	2	6
20 May	4	3	1	3
21 May	1	0	1	3
22 May	4	1	3	9
23 May	12	6	6	18
24 May	28	15	13	39
25 May	20	11	9	27
26 May	21	7	14	42
27 May	41	7	34	102
28 May	34	5	29	87
29 May	51	14	37	111
30 May	54	10	44	132
31 May	42	9	33	99
1 Jun	89	38	51	153
2 Jun	76	41	35	105
3 Jun	63	31	32	96
4 Jun	115	39	76	228
5 Jun	64	25	39	117
6 Jun	98	40	58	174
7 Jun	112	46	66	198
8 Jun	129	47	82	246
Total [d]	1,111	427	684	2,064

[a] Net count equals upstream count minus downstream count.

[b] Expanded to the hour.

[c] Sonar count set to zero because the expanded estimate was −12 fish.

[d] Total sonar estimate based on expanded counts from 14 May through 8 June.

APPENDIX E: DAILY RIVER STAGE AND TEMPERATURE FOR ANCHOR RIVER, 2010

Appendix E1.–Average daily river stage for the south fork of the Anchor River, 2010.

	Daily river stage average (cm) [a]									
Day	January	February	March	April	May	June	July	August	September	October
1	43.3	46.3	47.2	42.4	64.9	57.6	23.5	39.6	45.4	54.3
2	38.1	46.6	51.8	41.1	62.8	54.6	22.6	35.1	44.2	82.0
3	39.0	46.3	51.8	42.1	65.5	52.4	22.6	34.4	37.8	83.2
4	40.8	43.3	45.7	46.0	74.1	48.8	27.1	45.1	34.1	84.4
5	42.7	1,248.8	43.9	46.3	78.0	45.7	27.4	47.2	43.0	63.7
6	42.7	2,024.5	48.2	44.2	78.6	43.0	25.9	45.4	42.7	54.3
7	43.9	1,987.9	43.6	38.1	77.4	40.8	24.1	46.6	48.5	48.8
8	41.8	1,909.0	40.5	35.1	75.9	39.3	27.1	43.0	46.3	45.4
9	39.3	1,938.8	46.3	37.5	79.9	37.2	24.4	42.1	39.3	42.7
10	37.8	1,958.3	50.6	38.4	80.8	36.3	25.6	38.4	35.4	40.2
11	33.8	1,944.6	48.2	46.0	86.3	36.6	24.7	35.4	32.6	38.4
12	29.0	1,913.8	46.6	52.4	83.5	34.4	21.9	32.9	31.1	36.9
13	33.8	1,337.2	47.9	54.6	79.9	32.0	29.6	32.6	29.9	34.7
14	40.2	249.0	49.7	50.6	73.8	30.8	44.8	43.3	29.0	32.0
15	45.7	158.8	48.5	39.3	73.5	33.5	36.6	37.5	28.3	32.6
16	48.2	183.2	46.0	33.5	75.9	43.3	32.3	36.0	27.4	32.3
17	46.6	125.3	45.1	37.2	69.5	38.7	29.3	44.2	26.8	33.2
18	44.8	107.0	44.5	57.0	65.8	34.7	29.3	43.0	26.5	35.1
19	43.0	94.8	44.5	68.0	71.0	33.8	32.6	35.7	26.2	36.9
20	41.8	101.2	43.9	56.4	74.1	35.7	33.5	31.7	25.9	34.4
21	36.3	81.4	43.3	45.4	81.1	32.3	38.4	29.9	25.6	35.1
22	36.3	72.5	43.6	45.1	80.2	29.9	32.6	31.1	25.3	53.6
23	37.8	68.9	42.4	46.0	72.8	28.3	31.7	42.4	25.0	45.7
24	38.7	62.2	42.1	47.5	69.8	26.5	29.9	33.5	24.7	40.5
25	40.5	56.7	41.5	47.9	76.8	25.6	31.1	29.9	23.8	43.9
26	43.6	51.2	40.2	52.7	76.5	26.8	50.0	27.7	23.5	46.6
27	45.7	46.0	41.1	63.7	75.6	28.0	56.4	27.4	22.9	ND
28	47.5	45.7	43.9	68.0	73.5	29.0	42.7	28.0	22.9	ND
29	48.8		43.3	71.0	66.1	26.2	36.9	29.0	24.4	ND
30	49.1		42.7	71.9	66.4	24.7	35.1	28.7	33.2	ND
31	48.2		41.8		63.4		43.6	38.1		ND

Source: Ben Balk (U. S. Geological Survey (USGS), unpublished data).

Note: “ND” means no data.

[a] Stage data were collected at gauge station USGS 15239900 located approximately 11.4 RKM on the South Fork, Anchor River.

Appendix E2.–Average daily river temperature (°C), Anchor River, 2010.

	Daily temperature average (°C)														
	May			June			July			August			September		
Day	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
1	ND	ND	ND	ND	ND	ND	11.60	10.79	12.49	11.17	9.83	13.06	9.24	7.70	10.98
2	ND	ND	ND	ND	ND	ND	10.78	9.71	11.76	12.15	10.86	14.24	10.51	8.99	12.46
3	ND	ND	ND	ND	ND	ND	11.15	9.41	13.64	12.11	11.18	13.02	10.58	8.92	12.51
4	ND	ND	ND	8	8	8	11.64	9.83	13.45	11.21	10.76	11.93	10.20	9.73	10.71
5	ND	ND	ND	8	6	10	10.71	10.12	11.47	11.34	10.20	13.02	10.14	9.29	11.39
6	ND	ND	ND	10	8	11	10.58	9.31	11.95	11.29	10.64	12.00	9.69	8.30	10.88
7	ND	ND	ND	10	8	11	10.05	9.36	10.76	10.66	10.05	11.30	10.79	10.03	12.15
8	ND	ND	ND	10	8	12	9.81	9.31	10.30	10.13	9.36	10.59	10.18	9.36	11.20
9	ND	ND	ND	12.67	11.18	13.47	9.40	7.19	11.08	10.48	9.83	10.98	9.26	7.59	10.81
10	ND	ND	ND	10.64	8.72	13.16	10.15	9.26	11.37	10.60	9.76	12.00	9.57	7.77	11.52
11	ND	ND	ND	9.25	7.62	10.64	11.99	8.77	16.11	11.50	10.08	13.69	9.09	7.09	11.32
12	ND	ND	ND	10.13	6.89	13.74	13.71	11.15	16.94	10.97	10.20	11.78	8.97	6.81	11.37
13	ND	ND	ND	11.93	9.19	15.22	12.11	10.96	13.91	11.03	10.12	12.03	9.11	7.07	11.25
14	ND	ND	ND	11.12	10.03	12.49	11.38	9.44	13.76	11.33	10.64	12.39	9.55	8.59	10.49
15	ND	ND	ND	9.20	8.74	9.98	12.76	10.79	15.25	11.56	10.66	12.53	8.80	7.04	10.44
16	ND	ND	ND	7.39	6.97	8.67	13.20	10.93	16.01	10.79	10.27	11.44	7.67	5.85	9.56
17	ND	ND	ND	7.36	6.46	8.42	13.66	11.44	16.49	10.43	9.61	11.76	8.43	6.94	10.47
18	2	2	ND	8.11	7.09	8.97	12.95	12.22	14.41	10.49	8.52	12.53	8.90	7.77	10.59
19	3	2	3	8.36	7.62	9.26	12.25	10.86	14.41	10.57	8.32	13.02	7.34	6.31	8.54
20	5	2	7	9.08	6.99	11.32	11.81	11.03	12.70	11.16	8.97	13.74	7.62	7.02	8.32
21	5	2	7	10.31	7.70	13.09	11.36	9.24	13.83	10.40	8.54	12.15	8.33	7.24	9.93
22	4	2	6	11.69	10.20	13.93	11.59	10.74	12.68	10.43	9.51	11.49	8.57	7.70	9.63
23	4	3	4	12.06	9.16	15.37	11.24	9.93	12.41	10.32	8.07	12.87	8.16	7.39	9.36
24	5	3	7	12.20	9.76	14.53	10.17	9.61	11.20	10.86	8.37	13.62	5.96	4.79	7.34
25	6	4	7	11.72	10.88	12.73	9.80	8.92	10.91	11.05	8.54	13.83	5.46	4.25	7.19
26	6	3	8	10.66	9.78	12.00	9.60	9.06	10.25	10.79	8.89	12.58	4.24	2.74	5.80
27	6	4	8	10.37	9.95	10.96	9.87	8.57	11.52	10.84	10.15	11.76	2.95	1.45	4.56
28	5	3	6	11.04	9.06	14.03	10.28	9.36	11.05	10.76	10.25	11.78	2.72	1.59	4.06
29	8	6	9	11.02	10.03	12.56	10.45	9.51	11.90	10.03	7.90	12.51	4.20	3.46	5.21
30	8	6	10	11.79	9.61	14.84	10.57	10.15	10.93	10.97	9.61	13.16	5.75	4.92	6.89
31	6	5	7				10.26	9.66	10.93	9.24	8.54	10.59			

Source: Temperature data for 18 May–8 June collected at sonar-weir site using a hand-held thermometer. Temperature data for 9 June–30 September collected by Sue Mauger of Cook Inlet Keeper 0.1 RKM downstream of the resistance board weir.

Note: "ND" means no data.